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REDIMENTS

OF CHEMISTRY.

EDINBURGH:

WILLIAM AND ROBERT CHAMBERS;

AND GOR AND SMITH, LONDON.

1836.

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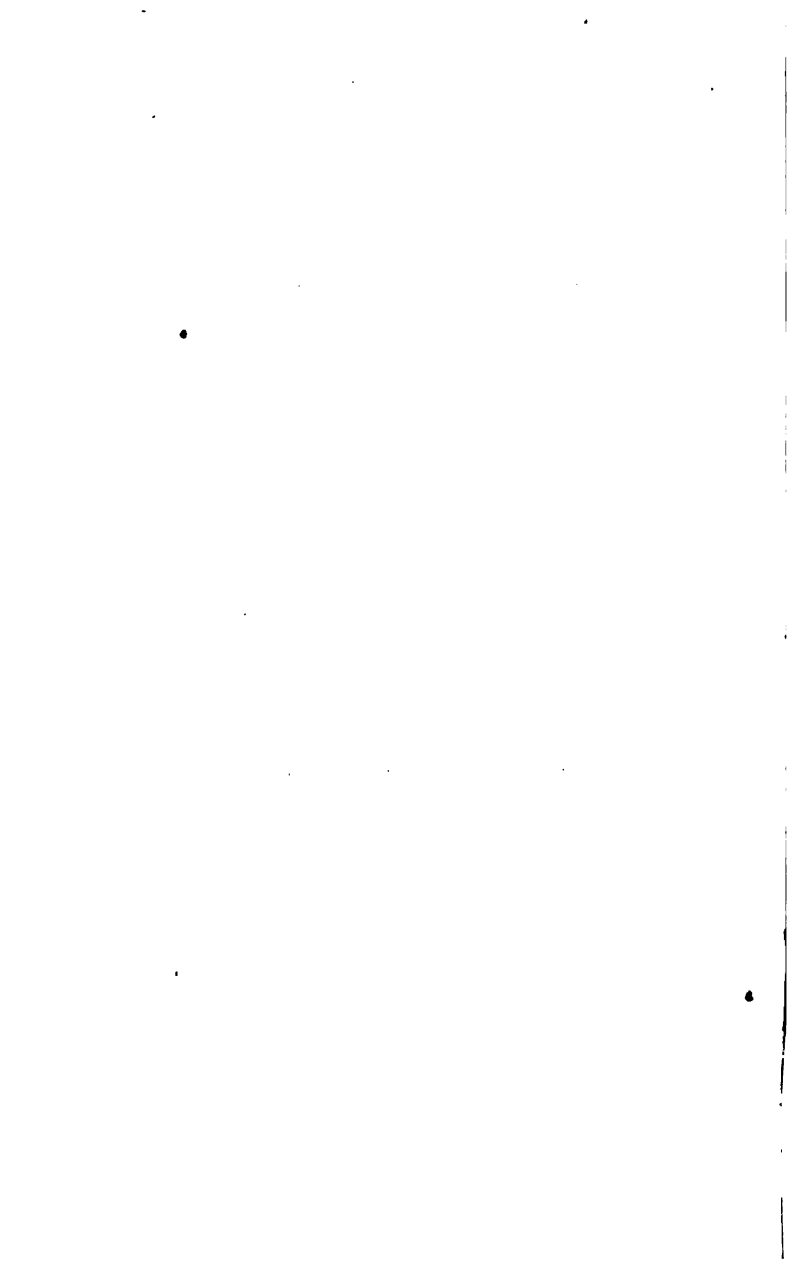
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CHAMBERS'S
EDUCATIONAL COURSE.

RUDIMENTS OF CHEMISTRY.

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WILLIAM AND ROBERT CHAMBERS.



RUDIMENTS OF CHEMISTRY;

WITH

ILLUSTRATIONS

OF THE

CHEMICAL PHENOMENA OF DAILY LIFE.

By D. B. REID, M.D. F.R.S.E.

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EDINBURGH:

WILLIAM AND ROBERT CHAMBERS;

AND ORR AND SMITH, LONDON.

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PREFACE.

THE object of this work is to facilitate the introduction of a Course of Chemistry, as an elementary branch of education, in all schools and academies, and to lay a foundation for the young pupil's future progress in Science, by awakening his mind to the nature of the material world in which he is placed. The plan adopted has been so fully explained in my papers on the "Study of Chemistry" in CHAMBERS'S EDINBURGH JOURNAL, that it is only necessary to remark, that the system of conjoining the study of the Practice at the same time with the study of the Theory, has been adopted as the most certain and interesting method of communicating instruction in this science. In endeavouring to combat the almost universally received opinion, that the Theory ought to be taught before the student is introduced to the Practice, I may be permitted to state, that my views have been confirmed by the experience of many years; and I may be allowed to quote the authority of CHEAPTAL, whose name is so well known as one of the most illustrious members of the National Institute of France. He remarks, "I was induced to adopt this plan," referring to his work on Chemistry applied to the Arts, "by the opinion I have long entertained, that the intelligence which elucidates Practice must succeed the latter. I am, in fact, convinced, from my own experience, that a man who is already acquainted with the mechanical and practical part of an art, receives instruction with much more advantage than another who is neither in the habit nor in the practice of its operations. For the latter, every thing is abstract; because the principles he is taught, apply to nothing that he already knows, and either are soon obliterated from his memory, or take a wrong direction there. The first, on the contrary, reflects on his own experience all the light that is transmitted to him; he sees in his practice the confirmation of all that is told him; he refers all that is said to all that he does; he compares the theory with his own operations, and, in a manner, identifies it with them."

The course of instruction recommended has not been proposed till a full trial was made of its practicability among young persons in all classes of society, and also in the School of Arts of this place, and other educational establishments. The total number of persons who have hitherto conducted a course of experiments according to the plan proposed, amounts to 1039. These included pupils from the following educational establishments; and, while the great majority were from ten to sixteen years of age, excepting the professional students alluded to in the first list, and amounting to 360, many individuals of all ages and professions, including also teachers and governesses, operated along with them.

Pupils attending Dr REID's Practical Classes for professional purposes, who, while conducting experiments with the usual apparatus, made use of the flat glass occasionally, so as to enable him to ascertain in what manner it might be most advantageously employed,	360
Pupils from the Edinburgh School of Arts,	140
From the Arbroath Scientific Association,	54
From the Montrose Scientific Association,	25
At Heriot's Hospital, Edinburgh,	120
At the Dalkeith Scientific Association,	120
Pupils from the High School, New Academy, St Mary's Parish School, Lancasterian School, and also from private seminaries for education,	120
At the Scottish Institution for the Education of Young Ladies,	80

A list of the apparatus and materials required for an elementary course of instruction in Chemistry, is given in the last chapter.

EDINBURGH, May 1836.

RUDIMENTS OF CHEMISTRY.

CHAP. I.—INTRODUCTION.

1. **MATTER** is presented to our notice in three very different conditions—in the solid, in the liquid, and in the gaseous form. **GASES** are very attenuated, like the air which we breathe. **SOLIDS** and **LIQUIDS** are much heavier than gases. **VAPOUR** is the name given to any matter which may be thin and gaseous, like the air, but differing from it, in being easily condensed into a liquid, as steam, which becomes water when exposed to cold.

2. Any matter from which nothing different from itself can be obtained is considered simple, and termed an **ELEMENT**: thus sulphur is called an element, because, do what we may with it, nothing different from sulphur can be procured. **COMPOUNDS** consist of different kinds of matter which may be separated from each other, as salt-water, from which the water may be separated by boiling, when the salt is left.

3. All masses of matter are composed of particles which are considered indivisible, and termed **ATOMS**. They must be exceedingly small, though their exact size is unknown, as a single grain can be divided into many millions of parts.

4. Put one grain of sulphate of iron, which contains only about a fifth part of iron, into fifty ounces of water, and add a few drops of a solution of the ferroproussiate of potassa. Every portion of the water will be seen coloured by the ferroproussic acid, one of the ingredients in the ferroproussiate, acting on the iron. A solution of the ferroproussiate is prepared at once by pouring upon it in powder ten times its bulk of water.

5. All kinds of matter tend to attract each other, mass to mass, and particle to particle. When a stone is lifted from the ground by the hand, the mechanical effort made by the hand overcomes the force with which the stone is attracted by the earth, and retained at its surface. When it is no longer supported by the hand, it falls or is drawn down to the ground by the attractive power of the earth.

6. Even air is attracted by the earth, and presses upon its surface: if we put a glass jar or a tumbler under water, allow the air it contains to escape, and invert it in the water, the water in the jar will not fall out so long as it is kept below the surface of the water in the trough. The air presses upon the surface of the water, and it again presses upon the water in the jar with so much force, that it supports water in any jar or tube even though it be 34 feet high. It does not press so much as to be able to sustain water to a greater height. Air presses upon each square inch of the surface of the earth with as much force as a weight of 15 lb.

Fig. 1.



7. When particles of the same kind of matter attract each other and unite, a mass, having the same properties as these particles, is formed, and then the term **COHESION** is used to express the action. But when particles of different kinds of matter unite, the particles thus formed have properties in which they differ more or less from those substances by whose union they are formed, and the term **CHEMICAL ATTRACTION** is then employed.

8. No substances can act chemically with each other which are not mixed together in the most intimate manner. By Heat, Light, and Electricity, many kinds of chemical action may be effected, which do not take place by mere mixture.

9. All **CHEMICAL ACTION** consists in **Combination** or **Decomposition**. **COMBINATION** signifies the union of particles of different kinds of matter, as when sugar unites with water. By **DECOMPOSITION** is understood the separation of particles of different kinds of matter which had previously been united, as the separation of salt and water from sea-water.

10. In both cases a change of properties in the substances uniting with or separating from each other is the characteristic feature of chemical action. Solids often become liquid or gaseous; liquids again frequently become gaseous or solid; and gases may be seen changed into solids or liquids; while heat and light often appear as these new arrangements take place.

11. Shake sand and water in a bottle; whenever the agitation ceases the sand falls; the water has no chemical action with it.

12. Suspend a piece of aqueous sulphate of copper (common blue vitriol) with a thread in a beer-glass full of water. The particles of both combine, and form a stream of blue fluid, which de-

ascends from the points where they are in contact. The solid is said to be **DISSOLVED**. The compound is called a **SOLUTION** of the solid.

13. Put a piece of an iron-rod, a few inches in length, into any glass-vessel, cover it with water, and pour upon it aqueous sulphuric acid equal to 1-6th of the bulk of water employed; so powerful is the chemical action exerted, that the particles of iron are torn from each other, and combine with particles of acid and of oxygen from the water. Hydrogen, the other element of water, is disengaged in the gaseous form.

14. Fill a beer-glass half full of water, and dissolve in it 10 or 12 grains of bichromate of potassa (a compound of chromic acid and potassa), adding it in powder. Dissolve as much acetate of lead (common sugar of lead), consisting of acetic acid and oxide of lead, in another similar glass with water, filtering the solution obtained, if it be turbid. On mixing the solutions, the chromic acid and oxide of lead combine, and produce a solid compound which falls down, and is said to be **PRECIPITATED**; the acetic acid and potassa unite and remain in solution.

15. Put a table spoonful of carbonate of soda (common soda) into a large beer-glass, cover it with water, and pour upon it aqueous sulphuric acid (oil of vitriol), as long as gas escapes. The chemical action consists in the union of the particles of the sulphuric acid and the particles of the soda; carbonic acid, the other ingredient in the carbonate of soda, being expelled with **EFFERVESCENCE**: this term is applied whenever gas escapes rapidly from any liquid.

16. Mix intimately two or three grains of chlorate of potassa with an equal weight of sugar, and touch the mixture with a glass slip previously dipped in aqueous sulphuric acid. It causes chlorine and oxygen to escape from the chlorate, which immediately inflame the sugar.

17. All substances, whether constituting the solid parts of the globe on which man dwells, the water of the ocean, the air which he breathes every moment of his life, the food with which he is nourished, the apparel with which he is clothed, the fuel with which he is warmed, or any of those numerous objects that minister to the wants, to the comforts, or to the elegancies of life in every civilized society,—in short, all bodies with which man is acquainted being constantly subject to a variety of chemical

- before it can produce, or can be resolved into, those placed after it.
- II. Each dot prefixed to a symbol indicates 1 equivalent of oxygen. A dot is frequently used instead of O for oxygen.
- III. Compounds are represented by the symbols of their element: SFe = Sulphuret of Iron, composed of sulphur and iron.
- IV. A figure prefixed to any symbol or symbols multiplies all that follow, unless a new sign intervene: $2H:S = 2H+2S$.
- V. A small figure placed after any symbol indicates that it is to be multiplied, and it does not refer to any other symbol, thus: $H^2C = 2H+C$.
- VI. Parentheses are often used in representing complicated combinations: $(2HC^2N+C^2NFe)+2K = \text{Ferropotassic Acid} + 2 \text{ potassa}$.
- VII. A figure prefixed to any symbols placed between parentheses multiplies them all, whether signs intervene or not: $2(2S+K) = 4S+2K$.
- VIII. In the symbolic and diagrammatic illustrations & is used to signify a substance added to another, but + is placed between substances already in combination. Thus, $S\&K$ signifies that sulphuric acid is to be added to potassa; but $S+K$ means sulphate of potassa, or sulphuric acid already combined with potassa.
- IX. Many vegetable acids are represented most conveniently by italic capitals, adding some succeeding letter where more than one have the same initial letter:

<i>A.</i> Acetic,	<i>Ci.</i> Citric,	<i>P.</i> Prussic,
<i>B.</i> Benzoic,	<i>G.</i> Gallic,	<i>T.</i> Tartaric.

23. All cases of chemical action represented symbolically should be extended on a slip of paper (or on a diagram-board by the teacher) in the following manner, as the best mode of enabling the student to become familiar with the changes which take place. I have been led to propose this mode of illustration, as being better suited to the present state of the science than the diagrams formerly used, and as numerous trials have assured me that the system of diagrams I have endeavoured to introduce has facilitated

the study of all who have had an opportunity of becoming acquainted with them.

24. To the left place the names or symbols of the substances employed. Arrange, in the next place, the names of the component parts under each other, or of the different matters that are separated as the action proceeds. Lines traced from these, and uniting in a point, indicate those materials which combine. The lines are dotted when the products are gaseous, composed of smaller lines where they are liquid, and plain where they indicate the production or separation of any solid substance.

25. For example, when sulphureted hydrogen decomposes carbonate of lead (carbonate of oxide of lead), the sulphur in the sulphureted hydrogen combines with the lead, the hydrogen unites with the oxygen in the oxide, and carbonic acid escapes from the carbonate. The following line explains the same action symbolically:

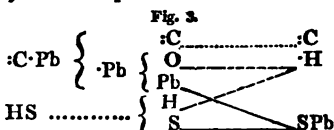


In the diagram it assumes the following form :

Fig. 2.

Materials used.	Composition.		Products.
Carbonate of Lead {	Carbonic Acid	22	22 Carbonic Ac.
	Ox. Lead { Oxygen	8	8 Water.
	Lead ...	104	
Sulphureted Hydrogen {	Hydr.	1	
	Sulph.	16	120 Sulph. Lead.

The above may also be represented in the following manner :



In studying the composition and properties of many compounds containing gases, it is necessary to become acquainted with the bulk which their elements occupy as well as their weight. The following Table should be frequently referred to, as it shews the composition by weight and by measure of the most important gaseous compounds. When the titles to the different columns are carefully studied, there will be no difficulty in understanding the table.

Symbols.	Names, Compounds, and their Elements.	Weight.	Bulk of the preceding weight.	Composition of the preceding Compounds by weight and by measure, with the symbols of the component parts.					
				Symbol.	Weight.	Measure.	Symbol.	Weight.	Measure.
H	HYDROGEN	1	<input type="checkbox"/>						
O	OXYGEN	8	<input type="checkbox"/>						
H	Oxide of Hydrogen	9	<input type="checkbox"/>	O	8	<input type="checkbox"/>	+	H	1
N	NITROGEN	14	<input type="checkbox"/>						
N	Oxide of	22	<input type="checkbox"/>	O	8	<input type="checkbox"/>	+	N	14
N	Binoxide of	30	<input type="checkbox"/>	O ²	16	<input type="checkbox"/>	+	N	14
N	Hyponitrous Acid	38	?	O ³	24	<input type="checkbox"/>	+	N	14
N	Nitrous Acid	46	<input type="checkbox"/>	O ⁴	32	<input type="checkbox"/>	+	N	14
N	Nitric Acid	54	?	O ⁵	40	<input type="checkbox"/>	+	N	14
N	Atmospheric Air	36	<input type="checkbox"/>	O	8	<input type="checkbox"/>	+	N	28
NH ³	Ammonia	17	<input type="checkbox"/>	H ³	3	<input type="checkbox"/>	+	N	14
S	SULPHUR	16	<input type="checkbox"/>						
S	Sulphurous Acid	32	<input type="checkbox"/>	O ²	16	<input type="checkbox"/>	+	S	16
S	Sulphuric Acid	40	?	O ³	24	<input type="checkbox"/>	+	S	16
HS	Sulphureted Hyd.	17	<input type="checkbox"/>	H	1	<input type="checkbox"/>	+	S	16
HS ²	Bisulphureted Hyd.	33	?	H	1	<input type="checkbox"/>	+	S ²	32
P	PHOSPHORUS	16	<input type="checkbox"/>						
HP	Hydruret of	17	?	H	1	<input type="checkbox"/>	+	P	16
C	CARBON	6	<input type="checkbox"/>						
C	Carbonic Oxide	14	<input type="checkbox"/>	O	8	<input type="checkbox"/>	+	C	6
C	Carbonic Acid	22	<input type="checkbox"/>	O ²	16	<input type="checkbox"/>	+	C	6
C ² H	Bicarburet of Hyd.	13	?	H	1	<input type="checkbox"/>	+	C	12
HC	Hydruret of	7	<input type="checkbox"/>	H	1	<input type="checkbox"/>	+	C	6
H ² C	Bihydruret of	8	<input type="checkbox"/>	H ²	2	<input type="checkbox"/>	+	C	6
OC ² H ³	ALCOHOL	23	<input type="checkbox"/>	2HC	14	<input type="checkbox"/>	+	H	9
OC ⁴ H ⁵	Sulphuric Ether	37	<input type="checkbox"/>	4HC	28	<input type="checkbox"/>	+	H	9
C ² N	Cyanogen	26	<input type="checkbox"/>	N	14	<input type="checkbox"/>	+	C ²	12
HC ² N	Hydrocyanic Acid	27	<input type="checkbox"/>	H	1	<input type="checkbox"/>			
Cl	CHLORINE	36	<input type="checkbox"/>						
Cl	Peroxide of	68	<input type="checkbox"/>	O ⁴	32	<input type="checkbox"/>	+	Cl	36
Cl	Chloric Acid	76	?	O ⁵	40	<input type="checkbox"/>	+	Cl	36
HCl	Muriatic Acid	37	<input type="checkbox"/>	H	1	<input type="checkbox"/>	+	Cl	36
I	IODINE	124	<input type="checkbox"/>						
I	Iodic Acid	164	?	O ⁵	40	<input type="checkbox"/>	+	I	124
HI	Hydriodic Acid	125	<input type="checkbox"/>	H	1	<input type="checkbox"/>	+	I	124
Br	BROMINE	75	<input type="checkbox"/>						
HBr	Hydrobromic Acid	76	<input type="checkbox"/>	H	1	<input type="checkbox"/>	+	Br	75

1st column contains the symbols of the compounds.

2d column contains their names.

3d column contains the weight of an equivalent quantity of each.

4th column contains the bulk or measure of the weight referred to in the preceding columns, hydrogen being taken as a standard of comparison. The square figure represents a whole measure, and the others indicate proportional quantities. Thus, in reading the third line, we say "H is termed oxide of hydrogen (water), its equivalent weight is 9, which corresponds with one measure."

Lastly, the remaining columns indicate the quantity by weight and by measure of the elements, in the proportion referred to in the preceding columns; the rest of the third line is therefore read in the following manner,—“being composed of oxygen 8, or half a measure; 8 parts of oxygen filling the measure half full, while one of hydrogen, which is so much lighter, fills it entirely.” Though the equivalent by weight of a compound is found by adding the equivalents of its elements, the corresponding bulk is often less than the bulk of both separately, the particles packing as it were in less space when combined.

CHAP. III.—CRYSTALLIZATION.

26. In many chemical operations, bodies are often procured in regular symmetrical forms, termed **CRYSTALS**; and the process by which they are formed is called **CRYSTALLIZATION**. Crystals are generally procured in one of the following modes:

I. By melting solids, or converting them into vapour by the application of heat, allowing them to return slowly to the solid form.

II. By slow deposition from fluids in which they have been dissolved.

27. Melt 2000 grains of sulphur cautiously in a flask, remove the heat, pour out half the liquid when the other has consolidated, and observe the crystals of sulphur.

28. Put alum into 8 or 10 ounces of water at a boiling heat, in a glass or earthen vessel, adding it so long as it is dissolved. Allow the liquid to cool; crystals are deposited. Hot liquids dissolve more of most substances than those that are cold, and if

charged with as much as possible when warm, part is deposited on cooling.

29. Expose a solution of oxalic acid or glauber salt to the air for some days on a shallow plate; the water is in part slowly removed, and crystals appear. By reducing these substances to powder, and shaking them with water so long as any is dissolved, a solution is very quickly procured.

30. Boil water in a glass-flask or iron-goblet, and add sulphate of soda so long as any is dissolved; pour the solution into a phial which it completely fills, and cork it tightly. No crystallization ensues when it is cold, but if the cork be then removed, crystallization immediately commences. If the air be not excluded as the solution in the bottle cools, it crystallizes in the usual manner.

31. Heat a tinned iron-plate before the fire, or over a lamp, till it is as warm as may be necessary to cause water dropped upon it to evaporate quickly with a slight hissing noise. Let the tin with which the iron is coated be then washed with a cloth, well moistened with a mixture composed of water 1 ounce, muriatic acid 1 dram, and nitric acid 1 dram. The cold fluid causes the hot tin suddenly to assume a crystalline form, and as the acids act upon the external particles of the tin, and expose those below, the crystalline arrangement is beautifully seen. When varnished, it retains its lustre; the varnish may be coloured of any tint that may be required.

32. Crystals and other solid substances which attract moisture from the air and become fluid, are said to *DELIQUESCE*; those that lose moisture under the same circumstances, and assume the appearance of a powder, are said to *EFFLORESCE*.

CHAP. IV.—HEAT OR CALORIC.

33. Chemical action being affected powerfully by heat, it is necessary to attend to its influence before entering upon the history of individual substances. Light and electricity also affect chemical action.

34. All the effects attributed to heat in common language, are produced by its entering and attaching itself to the substance affected, while those which are said to be caused by cold, arise in reality from a portion of heat leaving those substances with which it has been associated.

35. No one has been able to collect heat and shew it by itself; sooner or later it can penetrate every thing with which it may be surrounded. It is known only by its effects, and is considered a peculiar fluid, easily thrown into vibratory movements.

36. Heat tends always to pass from the hotter to the colder substance, till they acquire the same condition in this respect, when they are said to attain an EQUILIBRIUM of temperature.

37. The TEMPERATURE of any substance indicates its disposition to communicate heat to, or remove it from, any standard of comparison; if the temperature of the body be taken as a standard of comparison, those substances at a higher temperature communicate heat to it, while those at a lower temperature remove heat from it.

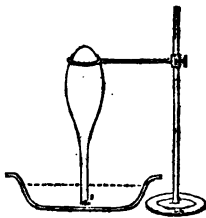
38. The principal EFFECTS produced by CALORIC are expansion, liquefaction, vaporization, evaporation, and ignition.

EXPANSION.—Bodies, with few exceptions, are expanded by heat; gases expand most, liquids come next, and solids last of all. When heated from 32 to 212, air expands 3-8ths of its volume, alcohol 1-9th, water 1-22d, and hammered iron 1-273d.

39. Measure the length of a cold iron-rod or bar; heat it to red-ness, and it will be found longer.

40. Fill a long narrow-necked flask nearly full of alcohol, and put it into boiling water; the alcohol as it expands rises in the neck of the flask.

41. Pour boiling water upon the same flask full of air, after in-
Fig. 4.



42. EXCEPTIONS.—Water contracts as it is heated from 32 to 39½. Many solids contract as they are melted by heat, expanding again as they become solid,—as ice, iron, antimony, bismuth, and many salts.

43. The communication of heat causes expansion to take place with great force; iron-bars, for instance, often cause rents in furnaces as they expand. A tough solid, such as iron, contracts with great force on cooling. Water, and other melted solids, expand

with great power as they become solid, bursting the vessels containing them when they are not allowed to escape in part by any aperture. A phial full of water, and corked tightly, bursts as it is frozen.

44. The common "THERMOMETER" contains a fluid which indicates the communication of heat, by expanding and rising in the stem, and the removal of heat (cold) by contracting and descending. Thermometers are graduated, and made to correspond with each other by observing the different points to which the fluid rises in freezing water and in boiling water; the space between these is in this country usually divided into 180 parts, 32 being placed opposite the point where the water freezes, and 212 opposite the point where the fluid stands when the water boils. Similar spaces are marked off upon the stem above and below these points, and numbered accordingly. It was at one time imagined that the greatest cold could make the fluid fall only 32 such spaces below the freezing point, the place to which it then fell being termed *zero*, and the notation commencing there. But much greater degrees of cold exist at different parts of the globe in winter, and may be produced artificially, so that the fluid in the stem of the thermometer often descends below that point, and is then said to be at so many degrees below zero.

45. LIQUEFACTION.—Heat is considered capable of melting all solids which it does not previously decompose. When any solid melts, much heat is required to effect this change in its form after it arrives at the melting point. Pour some boiling water upon ice at 32; the ice melts rapidly, but the water produced is no warmer than the ice; the heat is consumed in melting the ice. Pour boiling water upon ice-cold water, and the temperature is immediately increased.

When a fluid becomes solid, it gives out without cooling the heat which had rendered it fluid; the change proceeds slowly, as so large a quantity of heat must be withdrawn. As much heat is required to melt ice, as would raise the temperature of an equal weight of ice-cold water by 140 degrees; it melts, accordingly, with extreme slowness.



CHAP. V.—VAPORIZATION AND SPONTANEOUS
EVAPORATION.

46. **VAPORIZATION** signifies the rapid production of a thin vapour, as when water is boiled and produces steam. (See 1.) Water boils at 212, and does not become warmer as it boils, the heat applied being consumed in producing a change of form.

47. Hence, it is not economical to boil any substance quickly which may only require exposure to a boiling temperature, as all the heat that may be consumed in producing the vapour must cause an unnecessary expenditure of fuel. Put a thermometer into water, mark where the fluid stands in the stem as the water boils, and observe that it rises no higher, however long the boiling may be continued.

48. As much heat is required to produce steam from boiling water, as would elevate the temperature of an equal weight of boiling water by 1000 degrees, were it still to remain fluid; and steam, though it contains so much heat, is always at the same temperature as the water from which it rises.

49. Steam is transparent, colourless, and invisible, like the air. The white cloudy-looking matter usually called steam, is moisture produced by the condensation of steam. Steam occupies 1696 times as much space as an equal weight of water, and as it expands with great force, it often bursts and destroys vessels in which it is confined. When the power with which it expands is carefully regulated, so as to produce motion in machinery, it forms the most powerful engine man has invented, viz. the steam-engine.

50. When steam is exposed to cold, it condenses into water, giving out all the heat by which it was produced; and hence the severe burn it produces when condensed on any part of the body.

51. Boil a small quantity of water in the flask represented in fig. 4.; put in a cork when the air is expelled, and open the flask cautiously under water; the steam, which previously nearly filled the flask, being suddenly condensed, the pressure of the air forces up water to supply its place.

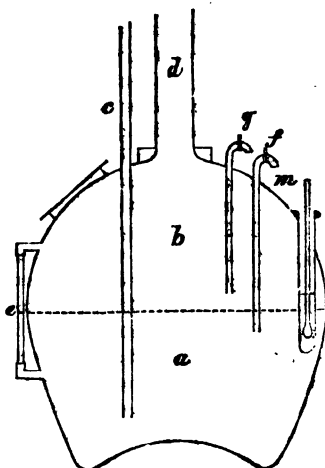
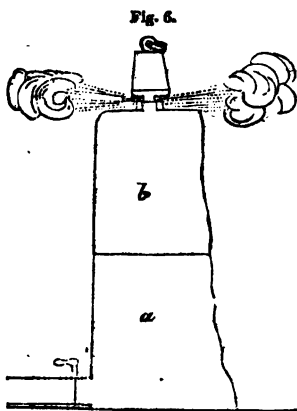
52. Water boils at a lower temperature than 212, when the air is not allowed to press upon it; fill the flask already alluded to (fig. 4.) one-half full of water, boil it briskly, and cork it while the steam is escaping, removing the heat immediately. The cold air condenses the steam, the cork prevents the air from entering, and

the water thus relieved from pressure begins to boil, the heat already in it being sufficient for that purpose. Put the flask into cold water; the ebullition then increases, the steam being still more effectually condensed. Put the flask into boiling water, the steam being no longer condensed presses upon the water, and prevents it from boiling.

53. If steam be not allowed to escape, and heat be continually applied by the fire, a higher and higher temperature is required to make the water boil, and the steam formed acquires more and more power, each successive portion compressing much of what had been already formed. It is then called **HIGH PRESSURE STEAM**, as it presses upon the sides of the boiler with great force. Boilers in which such steam is produced ought always to be provided with valves which the steam can push open, and by which it may escape before it becomes strong enough to burst the boiler.

54. Fig. 6. is a section of part of a boiler where the safety-valve is placed, the valve being loaded with a weight which the steam can raise before it acquires strength to burst the boiler. In examining the construction of boilers, the different parts noted in Fig. 7. should be attended to: *a*, *b*, the body of the boiler, filled

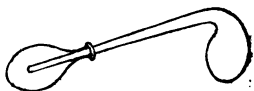
Fig. 7.



with water and steam; *c*, a pipe by which water is forced into the boiler; *d*, the steam-pipe; *e*, a glass tube or gauge placed so that the steam and water can enter freely into it, the water being always at the same height in it as in the interior of the boiler; *f, g*, two pipes placed so that the quantity of water in the boiler may be ascertained, when the glass tube is not used; if water comes from both, on opening the stopcocks, and when there is abundance of steam in the interior of the boiler, there is too much water, and if steam be disengaged from both, then there is too little; the boiler should be charged so that one gives steam and the other water, the level of the water in the boiler being between the extremities of the tubes where they terminate in the boiler: *m*, a thermometer to indicate the temperature of the water.

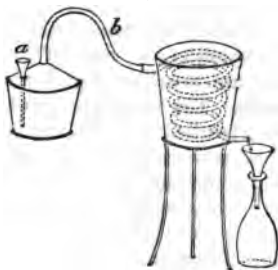
55. Distillation consists in the production of vapour by heat, which is afterwards condensed. The vessel in which the vapour is produced is called a **RETORT**; that in which the condensed vapour is collected must be kept cold, surrounding it with a cloth, and moistening it with water; it is termed a **RECEIVER**. Fig. 8. represents a retort and a receiver.

Fig. 8.



56. When a large quantity of fluid is to be distilled, it is introduced into a vessel called a **STILL**, the pipe from it leading to a vessel termed the **REFRIGERATORY**, as it is filled with cold water; in it the vapour is condensed.

Fig. 9.



57. **SPONTANEOUS EVAPORATION** is the term usually employed when vapour is produced slowly from a fluid, and without ebullition, as when water disappears from any moist surface. Water evaporates in large quantity from the surface of the ocean, and from the earth also, eventually producing the clouds, or condensing in the form of rain and dew. Snow is formed when the vapour is frozen at

once, and hail when rain is first produced, and then congealed by the cold.

58. Evaporation is always accompanied by the production of cold, when no heat is directly applied; the heat necessary for the production of the vapour is then derived from surrounding objects.

59. Pour some ether or any other volatile fluid on the back of the hand; great cold is perceived as it evaporates. If we blow upon it, the vapour resting on the surface is rapidly removed, evaporation proceeds more quickly, and a more intense degree of cold is perceived.

60. Evaporation proceeds more and more quickly the higher the temperature; the greater the extent over which the evaporating fluid is spread, the less the pressure of the air, and the nearer the evaporating substance approaches the boiling point. At the summit of high mountains, where the pressure of the air is less than at the surface of the earth, water boils at a lower temperature than 212; it is there above a large portion of the air which presses upon the surface of less elevated regions.

61. A current of air, when not loaded with moisture, promotes evaporation; hence the rapidity with which a wet surface generally dries on a windy day, the vapour resting upon it being pushed away, and a new portion rapidly formed.

62. Moisture is separated from the air in which it is diffused by a reduction of temperature. Sometimes it forms innumerable small vesicles; the mode of their production is not known. When they are associated together in large quantities, they produce clouds. The water evaporated from the surface of the ocean, &c., being purified from the materials with which it may have been mixed at the surface of the earth, and falling down afterwards in the form of rain, hail, snow, dew, or hoarfrost, becomes fitted for the various purposes for which it is so necessary in the animal and vegetable kingdoms.

63. The nearer the equator, the greater the annual fall of rain, and the less the number of rainy days. At Granada, 12 north Lat., the rain which falls annually would cover the surface to the depth of 126 inches, were it all to be deposited at the same time. In this country, it is calculated that the annual fall of rain would, on an average, cover the surface to the depth of 32 inches.

64. INCANDESCENCE.—All solids and fluids, which are not cor-

verted into vapour at a less elevated temperature, become luminous when heated to 800, in the dark, or when heated to about 1000 in day light. A red light appears at first, and gradually passes to a white as the temperature increases. This is observed equally in combustible solids, as charcoal, and in stony or other matters which do not burn; they are then said to be in a state of **INCANDESCENCE OF IGNITION**.

CHAP. VI.—COMMUNICATION OF HEAT.

65. Caloric is communicated by **CONDUCTION** and **RADIATION**.

66. When caloric passes slowly from one portion of matter to another in contact with it, it is said to be **CONDUCTED**, and the process is termed the **CONDUCTION OF CALORIC**. Metals are the best conductors, then liquids, and lastly gases. Gold, silver, and copper are the best conductors among solids; glass, bricks, and many stony substances, are very bad conductors; and porous spongy solids, as charcoal, hair, and fur, are the worst.

67. Put one end of an iron rod in the fire; the heat soon passes to it and along its particles to some distance from the fire. Put a glass tube or piece of wood of the same size as the iron into the same part of the fire; the heat extends a very little way beyond the part touching the fire, both these substances being bad conductors.

68. Clothing is generally made of bad conductors, that the heat of the body may not be conducted quickly to the surrounding air. Furnaces, where great heat is required, are built with porous bricks, which are very effectual in preventing the escape of heat; but when a stove is placed in the middle of any apartment, the fuel is surrounded with iron, that the heat may be quickly conducted to the air. The ice in an ice-house is surrounded with blankets or straw, to prevent the warm air coming too easily in contact with it.

69. When heat is applied to the upper portion of any liquid, expansion generally ensues, and it becomes lighter than the rest; it remains, therefore, resting upon the colder and heavier part. This may be easily shewn by boiling the upper portion of water in a long glass-tube, applying heat by a spirit-lamp. If the heat be applied near the bottom of the tube, the colder portion from above soon sinks below the hot expanded fluid, and pushes it up,

so that currents are continually produced, till the whole fluid is heated to the same point.

70. Similar movements take place in the air.—See the section upon Carbon, where illustrations will be given of the currents produced in a common fire.

71. Caloric is said to be **RADIATED** when it passes with great velocity from the sun, or from any warm body at the surface of the earth, moving through space, or through the air. It is believed in this case to move with the same velocity as light, viz. 192,000 miles in a second. Caloric is also radiated from warm bodies that are not luminous, as from the hand, or from hot water.

72. Radiant caloric is absorbed when it falls upon bodies having painted or rough surfaces, such as are presented by bricks and other porous solids, by many kinds of stony matter, and numerous animal and vegetable substances, and elevates their temperature as it is taken up. But brilliant and polished metallic surfaces absorb little heat; they reflect or turn it back again.

73. Take a piece of common tin-plate, and place it before the fire, it reflects most of the radiant heat, and becomes warmer with extreme slowness. Make the surface rough with a file or sand-paper, cover it with lamp-black, or black paint; it now absorbs heat quickly when exposed to the fire, and soon becomes warm.

74. Those bodies which are most powerful in receiving radiant heat when it falls upon them, are equally powerful in emitting it when they are warmer than surrounding objects. Thus, a vessel with hot water, having a rough, porous, or painted surface, cools much more quickly than when the surface is brilliantly metallic.

75. All bodies at the surface of the earth lose heat by radiation in a clear evening; they radiate more or less heat according to the nature of the surface; those that radiate most become colder than the others, and on these more dew or hoar-frost is deposited, the air coming in contact with them being cooled to the greatest degree, and unable, therefore, to retain all the moisture previously associated with it. The green leaves of vegetables are powerful in radiating heat, and are accordingly covered with the dew during the night, which is so necessary for plants when there is no rain.

76. In a cloudy night, as heat does not escape by radiation from the surface of the earth, the temperature never falls so much as in a cloudless sky.

CHAP. VII.—DISTRIBUTION OF CALORIC.

77. Caloric is unequally distributed over the globe. At the Equator the average temperature is $82\frac{1}{2}$; at the poles it is believed to be about 13 below zero. The higher we ascend in the air, the colder it becomes; the summits of very high mountains are always covered with snow. The interior of the earth is generally believed to be at a very elevated temperature; many consider the numerous volcanoes that appear at its surface to arise from a central fire.

78. Caloric tending always to an equilibrium, the heat at the warmer portions of the surface of the globe is carried in part to those that are colder by currents in the air and in the ocean, so that the extreme severity, both of heat and cold, is thus mitigated.

79. The amount of caloric is not the same, even in equal weights of different bodies at the same temperature; as a wide jar requires more liquid to fill it to a certain height than is necessary to fill a narrow jar to the same height, so, many different bodies require more heat than others to elevate their temperature to a fixed point. Take a small jug of boiling water, and mix it with an equal bulk of cold water, previously placed in a flask or basin, and examine the temperature with a thermometer. Then mix equal bulks of boiling water and cold oil in another vessel, the temperature of the mixture will be greater than before; the heat which the boiling water loses elevating the temperature of the oil by a greater number of degrees than an equal bulk of cold water.

80. PRODUCTION OF HIGH TEMPERATURES.—Heat is developed principally by burning inflammable substances. (See Air and Carbon). It may also be excited by mechanical action and by electricity. A most intense heat is produced when the rays of the sun are collected by a burning-glass, which bend the heat passing through it in such a manner that much of it falls upon one point.

81. Hammer a piece of iron on an anvil, it soon becomes very warm. Rub a thin piece of phosphorus, not greater than a quarter of a grain, with a piece of glass, after placing it in paper, it soon inflames when exposed to the air.

82. PRODUCTION OF LOW TEMPERATURES.—By placing volatile fluids where they evaporate rapidly, as in a current of air,

considerable cold is produced. Pour any volatile fluid on the hand, and blow upon it; it evaporates with great rapidity, producing cold as the vapour formed removes heat from the hand. See 58. and 59.

Again, solids which are rendered fluid without the application of heat become very cold. Mix two parts of snow or pounded ice with one of salt; the mixture soon becomes fluid, and the temperature falls 41 degrees below the freezing point of water, if large quantities be used, and the snow and salt in a minute state of division.

Mix 16 ounces of water with 5 of nitre and 5 of sal-ammoniac in fine powder; the temperature falls about 40 degrees as the salts dissolve in the water. Boil off the water, and collect the dry salts, which may be used again and again for the same purpose.

CHAP. VIII.—LIGHT AND ELECTRICITY.

83. Light is intimately associated with heat, and appears in all solids and liquids intensely heated. Light influences powerfully many cases of chemical action, and appears frequently in numerous cases of combination and decomposition.

All plants placed in a dark situation send out shoots to any opening where light may enter.

84. To shew the influence of light on chemical action, add a few drops of a solution of the nitrate of silver to a glassful of a solution of common salt; the chlorine, one of the elements of the salt, falls down with the metallic silver, in the form of a white compound. Put it into a dark place, and it remains white; but expose it to the light of day, or to the direct rays of the sun, and it soon becomes dark.

85. The tint of coloured bodies depends upon the kind of light emitted from them. The beam of pure white light was considered by Newton to consist of seven different kinds of light united together, viz. red, orange, yellow, green, blue, indigo, and violet. Many now consider that it is composed of only three kinds of coloured light, viz. red, yellow, and blue, as all other tints can be produced by them.

86. Clothing of different colours attracts odorous matters with different degrees of power. The darker the tint the greater the

power of attraction, and the longer is the odorous matter retained. (Dr Stark.)

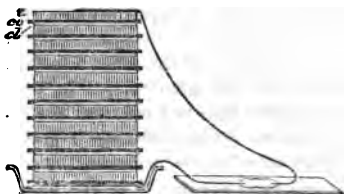
87. Besides heat and light, another power, viz. **ELECTRICITY**, acts with great energy upon all kinds of matter. There is no substance with which man is acquainted that does not contain it, and it is continually set at liberty in numerous cases of chemical action, or taken up in others, according to the nature of the changes that ensue. When accumulated in large quantity, and discharged from one kind of matter to another, as when it passes from the clouds to the earth, it produces thunder and lightning. On a smaller scale it is produced by the friction of different substances with each other, or by the chemical action of acids on metals, when it may be made to produce a number of chemical changes, by passing it through the materials to be affected. It is usually termed **GALVANISM** when produced by chemical action.

88. Rub a large stick of sealing wax briskly with a silk handkerchief, electricity is produced, and light substances, as a feather or a small piece of paper, are attracted by the wax. If the experiment be performed in a dark room, small sparks of electricity may be observed on approaching the finger to the wax.

89. Procure twelve plates of copper and twelve plates of zinc, place them in the order

Fig. 14.

represented, with a piece of cloth between each pair, the upper and lower plates having copperwires soldered to them, tipped at the extremity with small wires of platinum.



The plates need not be more than two or three inches in diameter, and the cloth must be moistened with a liquid, composed of 1 part, by measure, of sulphuric acid, 2 of nitric acid, and 60 of water. The whole of the apparatus may be placed in a small plate or basin. Sometimes each zinc plate is soldered to a copper plate; they can be arranged more conveniently in this way than when separate.

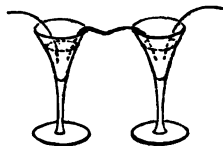
90. Place any of the following substances in solution upon a small slip of glass or paper; a drop of the solution will be sufficient. The platinum extremities of the two wires must be dipped into the solution, but not so as to touch each other. The electri-

city is developed as the acid fluid in the cloth acts upon the zinc, accumulating in one of the wires and passing to the other, the materials in the solution being affected as it passes through them, and decomposed.

Materials used.	Products.
1. Sulphate of soda, composed of sulphuric acid and soda, resting on cabbage-paper.	1. The acid accumulates at one wire, and reddens the paper; the alkali at the other, and turns it green.
2. Iodide of potassium, composed of iodine and potassium, mixed with a little starch.	2. The iodine is immediately separated, and forms a blue compound with the starch.
3. Acetate of lead (common sugar of lead).	3. Metallic lead is deposited in small crystals.
4. Sulphate of copper.	4. Metallic copper is deposited in the same manner as the lead.

91. Put a tea-spoonful of sulphate of soda into a cup, and dissolve it in hot water; pour a little cabbage-blue (see Colouring Matter) into the solution, and put a portion into two glasses, connecting them, as represented in fig. 11, by a piece of linen or cotton cloth, previously moistened in the same solution. On putting one of the wires into each glass, the acid accumulates in one, turning the blue to a red, and the alkali in the other rendering it green. If the wires be now reversed, the acid accumulates eventually in the glass where the alkali appeared, while the alkali passes to the glass where the acid was.

Fig. 11.



92. Moisten the fingers with the diluted acid used for the cloth, and hold one wire in each hand; the electricity is felt feebly as it enters the fingers, and passes through the body from one wire to another. With a large apparatus, the most violent convulsive movements, and even death, may be produced.

93. Electricity passes readily through metals and charcoal, and is attracted by all pointed objects in great quantity. Hence, in a thunder storm, all elevated situations and metallic bodies should be avoided; it is dangerous also to be near trees, as the electri-

city frequently passes down by them to the earth. Pointed metallic rods are often attached to buildings, descending into the moist ground or into a well, that the electricity may pass by them into the earth. The safest place in a thunder storm is the middle of an open field, at a distance from all high objects; or at home, in the middle of a room, away from the walls, the chimney, and the window.

CHAP. IX.—WATER AND ITS ELEMENTS.

94. Water, or oxide of hydrogen, is composed of hydrogen 1 + 8 oxygen. Equivalent 9. W. of 1 cubic inch, 252.458 grs. For the action of heat upon it, see Liquefaction and Vaporization.

95. Transparent, colourless, tasteless, and inodorous, when pure, leaving no residuum when evaporated to dryness. Its compounds are termed **HYDRATES** or **AQUEOUS COMBINATIONS**. Dissolves numerous vegetable, animal, and mineral substances; is decomposed in many cases of chemical action, affording oxygen or hydrogen to the substances which affect it. Absorbs or condenses many gases, most of which are expelled on boiling.

96. **PURE WATER**, for chemical purposes, is prepared by distillation (see 55.), as it is no where obtained absolutely pure in nature; the impurities remain in the retort or still. Rain and snow water are the purest natural waters; even these must be boiled to expel air, when water is required absolutely pure.

97. **SPRING WATER** is not so insipid and tasteless as distilled water, containing portions of air, as well as saline or earthy matter which it may have dissolved while flowing in contact with various rocks and minerals. **RIVER WATER** is similar to spring water, but oftener loaded with impurities. **WELL WATER** is still less pure. Water is said to be **HARD** when it is so loaded with foreign matter that it decomposes soap, producing a curdy precipitate, so that it is unfit for washing, or for dissolving many substances in daily use.

98. **MINERAL WATERS** include all those which are so charged with foreign matter as to acquire peculiar properties. The following are the principal varieties of mineral waters, and their properties should be studied along with the properties of those substances in which they abound; these are printed in italics, and by referring

to them as they are described in succeeding chapters, the tests by which they are distinguished will be seen.

- I. ACIDULOUS mineral water abounds in *carbonic acid*.
- II. SULPHUREOUS mineral water contains *sulphureted hydrogen*.
- III. SALINE mineral water contains principally *soda, lime, or magnesia*, united generally with *sulphuric and muriatic acids*.
- IV. CHALYBEATE mineral water contains *iron*, united with *sulphuric or carbonic acid*.

99. To acquire at once a general knowledge of the properties of any water, the following experiments may be tried :

- I. Evaporate a drop on a flat slip of glass, holding it before the fire, or above a small lamp or candle. Small rings only appear where the water rested, if it contained only a minute quantity of foreign matter ; but a crust is seen, if it be loaded with saline or earthy matter, and the crust has an ochry tint, if iron be present.
- II. Pour some of the water into a wine glass, and add a solution of litmus ; it is reddened if any acid matter be present.
- III. Mix another portion with a little soap ; a curdy matter appears if it abound in earthy matter.

OXYGEN.

100. This element is a gas. It is 16 times heavier than hydrogen, and forms more than one-half of the globe, constituting 8 tons in every 36 of air, 8 in every 9 of water, nearly a half of the more abundant earths, silica and alumina, besides being found in almost all vegetable and animal matters. It received the name of oxygen from Greek words, signifying to produce a sour substance, many of its compounds being acid.

101. OXIDES are compounds of oxygen which are not acid. OXIDATION signifies the union of any body with oxygen. Substances which communicate oxygen with facility to other matters are called OXIDATING AGENTS ; the principal are air, water, and acids and salts containing oxygen. DEOXIDATING AGENTS include those substances which are powerful in removing oxygen, as carbon, hydrogen, phosphorus, iron, and many other metals.

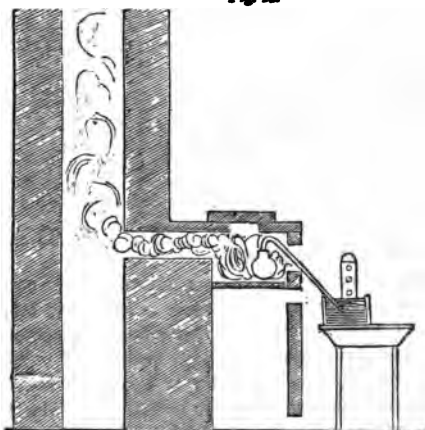
102. Oxygen is particularly distinguished by its power of supporting combustion ; all inflammable substances burning brilliantly in it. Introduce a wooden match red hot at the end into a jar

of oxygen, or a suspended candle (fig. 12.) with the wick red; it burns brilliantly, and the flame is rekindled. In all cases Fig. 12. where ordinary inflammable matter burns, it acts upon the oxygen which is contained in the air, and combines with it. The inflammable matter is not lost or destroyed, but often becomes invisible like the air itself, as it forms gaseous compounds.



103. PREPARATION.—Binocide of manganese is heated to redness in an iron bottle placed in an open fire, or resting in a furnace, as in the annexed cut, fig. 13. The bottle should be large

Fig. 13.



enough to contain several ounces of the binocide; and the oxygen which is not required for immediate use should be collected in beer bottles previously filled with water, and employed afterwards as it may be required. The bottles should be corked under water, the corks being afterwards covered with lard, and a piece of cloth tied round them.

104. The furnace represented here is of a form extremely convenient for numerous operations; and, where the vent is exposed on every side, other furnaces may be placed around it. The area for the fuel may be made from 9 inches to a foot square, and the small chimney from 5 to 6 inches in diameter. A front view is given in fig. 14, to shew the manner in which the bricks are ar-

ranged in small pieces, so as to be taken out and adjusted according to the experiment to be performed. The chimney works well when it is 9 or 10 inches square, and about 10 or 20 feet high. A shelf is placed before and below an aperture in the chimney; and when it is required to carry off fumes from any mixture, the vessel is placed in the same situation as the flask, the plug being removed from the aperture, which is at other times closed.

105. When the binoxide is heated in the furnace, 88 grains give 8 of oxygen, and every grain may be considered as equal to 3 cubic inches of gas.

106. Where there is no opportunity of operating with a furnace, 1000 grains of the binoxide in fine powder may be mixed in a retort with an equal weight (about $1\frac{1}{4}$ ounces by measure) of aqueous sulphuric acid; in this case every 44 grains give 8 of oxygen; but this operation is not so well adapted for preparing a large quantity of oxygen. The retort must be heated by a chauffer or lamp, and the heat withdrawn whenever the gas ceases to escape, otherwise the water might pass into the retort and break it, being forced up by the pressure of the air as the gas still in the retort cools and contracts.

107. The trough (fig. 15.) is usually made of wood or tinned

Fig. 14.

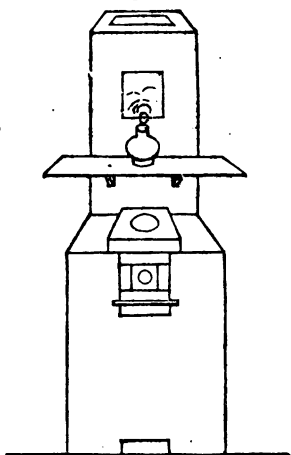
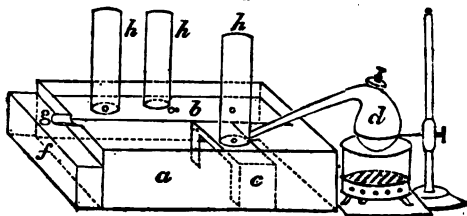


Fig. 15.



iron, about 24 inches long, 12 broad, and 8 deep. The shelf and moveable stool may be made 7 inches high. Fig. 1. p. 2. shews a section of the trough without the stool.

108. Tin trays (fig. 16.) or small plates are placed below the jars of gas under water, when they are to be removed from the trough, and used for experiments. The jars or bottles used for collecting the gas must always be filled with water to expel air, before any gas is collected.

Fig. 16.



109. Jars of the form fig. 17, are often used to transfer oxygen or other gases to a bag or bladder, adjusted mutually to each other by moveable connectors. The jars being filled with gas, and then depressed in water, the gas is forced into the empty bag, which is slowly distended. The bag having been withdrawn, a nozzle is fitted to it, by which the gas can be directed upon any object when it is compressed, fig. 18.

Fig. 17.

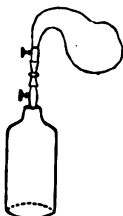


Fig. 18.



HYDROGEN.

110. Hydrogen is a gas, and the lightest of all known substances; it is nearly $14\frac{1}{2}$ times lighter than air; 100 c. i. weigh only 2 grains and a fraction. Its name is derived from two Greek words signifying to produce water, as it is formed when 1 part of hydrogen unites with 8 of oxygen.

111. Hydrogen constitutes 1-9th of the water of the globe, and is also found in almost all animal and vegetable substances.

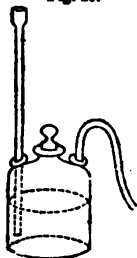
112. PREPARATION.—Put 500 grains of zinc in fragments into a common beer-bottle; pour upon them 3 ounces of water, and add 5 drachms of aqueous sulphuric acid. The acid, the oxygen of part of the water, and the metal, combine, producing sulphate of zinc; the hydrogen is disengaged, and may be collected at the pneumatic trough in jars; a cork with a bent tube is adapted to the neck of the bottle (fig. 19.) to convey the gas to the jars, which can be arranged as in fig. 15, p. 26.

Fig. 19.



113. Zinc is procured in fragments by melting it, and pouring it from a height into water. Iron-filings may be substituted for zinc; the acid should then be added slowly, and an apparatus of this form (fig. 20.) is convenient, as it may be introduced by the long tube in small quantities at a time, to prevent the action going on too briskly. Small nails may be used instead of the filings.

Fig. 20.



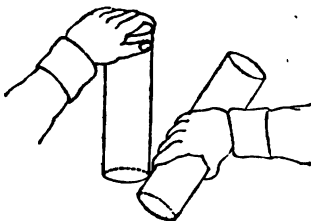
114. Invert a jar with hydrogen as described in 108, and apply a lighted match as the cover is taken off; the hydrogen burns rapidly, uniting with the oxygen of the air, and producing water.

115. Inflame hydrogen gas in another jar, keeping the mouth downwards; the light hydrogen mixes this time more slowly with the air, and takes a longer time to burn.

116. Take any small jar or phial, fill it with oxygen, and then introduce the oxygen into a larger and very strong jar; fill the small jar twice with hydrogen, and mix it with the oxygen in the larger jar. Invert the mixture and apply a lighted match; an immediate detonation ensues, and water is formed.

Fig. 21.

117. Practise transferring gases from one jar to another under water, holding them as in Fig. 21.

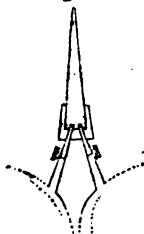


118. Transfer hydrogen into a bag with a small nozzle (see 109); press it so as to direct a stream upon a small portion of spongy platinum less than a pea, and supported loosely in a small coil of platinum wire; the air, or oxygen, acting on the platinum at the same instant with the hydrogen, the metal soon becomes red hot, and the hydrogen is inflamed.

119. If two bags be taken, the one with oxygen, the other with hydrogen, and a stream of gas pressed out from both at the same instant, so that they unite and produce one jet of flame, an intense degree of heat is excited; iron-wire held in the flame quickly

burns; small fragments of copper, zinc, antimony, lead, and tin, burn with great rapidity, if supported on charcoal; small pieces should be taken, less than a pea. Lime, tobacco pipe-clay, and other earthy substances, become intensely luminous in this flame. The hydrogen requires only half its bulk of oxygen to be mixed with it; and the gases are apt to explode if they be mixed in one vessel, unless the tubes be arranged in a particular manner to prevent the flame from returning. The figure shows the manner in which the nozzles from the bags are connected in another nozzle, at the extremity of which the flame is produced. These nozzles are usually made of brass, and about 1-50th of an inch in diameter at the extremity, or rather less.

Fig. 22.



120. *Symbols of processes described, with a translation :*

$\text{H\&O} = \cdot\text{H}$. Hydrogen and oxygen produce water

$\text{:S\&H\&Z} = \text{:S'Z\&H}$. Sulphuric acid, water and zinc, produce sulphate of zinc and hydrogen.

$\text{:S\&H\&Fe} = \text{:S'Fe\&H}$. Sulphuric acid and water, and iron, produce sulphate of iron and hydrogen.

CHAP. X.—AIR AND ITS ELEMENTS.

121. Air is not an element, but a compound of two gases, oxygen and nitrogen, and its chemical properties depend principally upon the oxygen it contains. Thus the oxygen combines with inflammable matter during combustion, it acts on the blood in the lungs when animals respire, and its influence may be traced in numerous operations continually going on at the surface of the earth. When the oxygen of the air is consumed, inflammable substances do not burn in it, and animals introduced into it immediately die. Hence the great importance of removing air vitiated by combustion or respiration, and introducing into every apartment fresh air from a pure source. Much of the oppression and headache of which many persons at times complain, either arises entirely, or at least is much aggravated, by breathing for a

great length of time in an atmosphere vitiated by a crowded assembly, or imperfect ventilation.*

122. Minute quantities of moisture and carbonic acid are found in air in every part of the globe, which have an important influence in numerous changes at the surface of the earth; and though large quantities of oxygen must be continually consumed, still the composition of the air does not vary, oxygen being again restored to it, principally, it is believed, by the action of the leaves of plants during sunshine.

123. Put a short lighted candle, about an inch long, upon the shelf of the pneumatic trough (Fig. 15.), supporting it above the water on any small metallic stand (Fig. 23.) Place over it a glass jar, allowing it to rest upon the shelf. The air is at first expanded by the heat, and a little escapes; the candle soon begins to burn more dimly as the inflammable matter it contains consumes the oxygen, and in a short time it is extinguished. Water is now forced up by the pressure of the external air to supply the place of the air expelled at first, and also of part of that which is consumed, a portion of the product being condensed by the water.

Fig. 23.

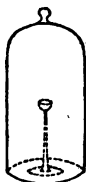


NITROGEN.

124. This gas abounds in the air, forming 4-5ths of its bulk, and is also found in considerable quantity in animal substances, and in salts called nitrates. It is observed only in a few vegetable substances.

125. Put 8 or 10 grains of phosphorus into a tin or copper cup, supported several inches high (Fig. 24.), and place over it, when inflamed, a jar about the size of a common beer-bottle, operating at the pneumatic trough, as in Fig. 24. The phosphorus should never be touched directly with the hand, and must be dried well between folds of blotting paper before it is used. When the white compound of the phosphorus and oxygen of the included air has combined with the water, nitrogen gas remains transparent and colourless.

Fig. 24.



126. Transfer it under water to another jar, previously filled

* For illustrations of ventilation, see Carbon, Fire-places, and Furnaces.

with water, holding them in the manner shewn in Fig. 21; or invert the jar with a cover, keeping in all the water, and introduce a suspended candle (Fig. 12.) into the gas; it is immediately extinguished. The nitrogen may be contrasted with oxygen in another jar, the candle being extinguished in the one, and re-kindled in the other, many successive times.

127. Nitrogen neither supports combustion nor respiration. It is disengaged with great facility from numerous compounds, many of which explode violently as it is separated.

NITRIC ACID.

128. The elements of air, united in a different proportion, form nitric acid, one of the most corrosive and powerful acids; diluted with water it constitutes aquafortis.

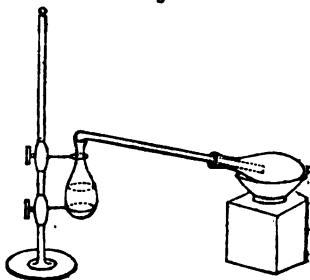
129. Compounds which have a sour taste, and redden blue vegetable colouring matter, are termed acids, though a few of them are very feeble in these respects.

130. Fill a glass retort about 1-3d full of a mixture of equal weights of aqueous sulphuric acid and nitrate of potassa (common nitre); heat the mixture with a lamp or chauffer, and collect the vapour that distils over in a receiver, which must be kept cold; if the vapour comes over more rapidly than it can be condensed, the heat must be moderated.

131. A flask with a bent tube fitted to it may be used instead of a retort, being luted to it with a mixture of clay and sand, when the materials have been introduced. Fig. 25.

132. The process should be continued till a quantity of acid be obtained, at least equal in bulk to the aqueous sulphuric acid employed. Part of the acid is generally decomposed, and a ruddy vapour produced which tinges the acid of various hues; it is called nitrous acid. The sulphuric acid remains in the retort with the potassa of the nitre, and the nitric acid passes into the receiver united with water, which it takes from the aqueous sulphuric acid employed.

Fig. 25.



133. Add a drop of the acid to water in a beer-glass, coloured with vegetable blue; it is immediately reddened.

134. Cover a tea-spoonful of iron-filings in another beer-glass with water, and pour upon them small quantities of acid at a time till a brisk effervescence appears. The iron takes oxygen from the acid, and many gases are disengaged composed of nitrogen with less oxygen than is found in the acid.

135. Heat two table-spoonfuls of charcoal powder to redness in a crucible, and pour upon it aqueous nitric acid in a very slender stream; the charcoal burns rapidly, taking oxygen from the acid.

136. Nitric acid is always associated with water as usually procured, and should be kept carefully in stoppered phials, as it is very corrosive, and emits acrid fumes. It is transparent and colourless when there is no nitrous acid present, and if concentrated, a phial that holds 1000 grains of water will contain about 1480 of this acid. It is often contaminated with sulphuric acid or chlorine, which may be detected by solutions of nitrate of baryta and nitrate of silver. The acid should be diluted in a wine-glass, before the tests are applied, with 6 or 8 times its bulk of distilled water. The tests produce no effect in pure acid; sulphuric acid gives a white precipitate with baryta, and chlorine produces the same effect with the silver. The tests must be tried in separate glasses.

137. Evaporate a portion of the nitric acid on a broad slip of glass, or in an evaporating basin, till none is left. If any solid matter remain, it is also to be regarded as an impurity.

138. The other compounds of nitrogen and oxygen are represented in the Table, page 8. They are produced when nitric acid or its compounds are decomposed.

139. **OXIDE OF NITROGEN**, commonly called Intoxicating Gas, can be respired for a minute or two without danger; it produces great excitement in general, accompanied by immoderate laughter, and violent muscular action. Its effects pass away very quickly.

140. **BINOXIDE OF NITROGEN** is also gaseous, and, when mixed with air or oxygen, produces dense, acrid, ruddy fumes of nitrous acid.

141. Nitrous acid generally appears as a ruddy vapour when ni-

tric acid is decomposed, or when the binoxide acts on the air and attracts more oxygen.

CHAP. XI.—SULPHUR AND PHOSPHORUS.

142. Sulphur has a fine straw-yellow colour; abounds in many volcanic countries, where it is believed to have been separated from its various compounds by the action of heat. It is also prepared artificially by heating compounds in which it is combined with metals.

143. Hold a roll of sulphur over a powerful lamp; it soon falls in pieces, the exterior portion expanding, while the rest is rigid. Sulphur is a bad conductor of heat.

144. Melt sulphur in a Florence flask, and pour it, whenever it is fluid, into water; it immediately becomes hard and brittle.

145. Heat another portion, after melting it, till it becomes thick and viscid; pour it, in a very slender stream, into water; it is now transparent, soft, and elastic, but gradually returns to its usual form.

146. Heat sulphur in a small retort, the vapour condenses in the neck of the retort, or in a receiver which may be connected with it, in the form of a yellow powder, usually called Flowers of Sulphur.

147. Pour melted sulphur into a conical wine-glass, previously moistened very slightly; it consolidates quickly into a crystalline mass. Observe the crystals as they shoot across the liquid.

148. Dip small pieces of wood into melted sulphur; a portion of it adheres to the wood, and common sulphur matches are formed.

149. Press any seal or stamp upon melted sulphur resting upon paper; it takes a very accurate impression. Metallic substances are very apt to be discoloured by sulphur.

150. SULPHUROUS ACID is formed when sulphur burns in contact with the air or pure oxygen. It is a pungent suffocating gas; water can condense thirty-three times its bulk, acquiring its odour. When sulphur is burned in oxygen, a very beautiful blue light appears. The same apparatus may be used as in burning phosphorus in air to prepare nitrogen (See 125), or a few fragments of sulphur may be kindled in a copper-cup, suspended by a wire, and introduced into a phial, vase, or flask (Fig. 26.), filled with oxygen gas.

Fig. 26.



151. SULPHURIC ACID is the most important compound of sulphur, and is termed **AQUEOUS** in the condition it is usually met with, 40 of acid being combined with 9 of water. It is prepared by mixing sulphurous acid gas, formed by burning sulphur, with nitrous and nitric acid, in a large chamber lined with lead. When properly concentrated, it is a dense oily-looking fluid, much heavier than water. It is much employed in decomposing compounds containing acids, corrodes animal and vegetable matter, and is intensely acid.

152. Pour three or four drops upon the fire, or upon a red-hot iron, where the fumes can be carried away; dense white vapours immediately appear.

153. Aqueous sulphuric acid should never be mixed with water in a glass measure, or any other thick glass vessel, as the sudden heat produced often causes them to be broken. Pour 3 ounces of water into a thin flask, capable of holding 10 or 12, and mix with it in the flask $4\frac{1}{2}$ ounces, by measure, of the strongest acid. Great heat is immediately produced; if a tube with cold water be placed in the mixture, it soon begins to boil. If the flask be very thin it may be dipped into cold water, till it is nearly covered, and immediately removed; the small portion of water adhering to the glass outside evaporates quickly, and much vapour is observed.

154. Try the action of a few drops of this acid on vegetable blue, as in 133.

155. Put a few chips of wood into a wine-glass, and mix them with a little of the acid; the wood is decomposed, and becomes black from the separation of part of the carbon.

156. Take two beer-glasses with water, and put into each a dram of the aqueous acid; into one pour a few drops of any solution of baryta, sulphate of baryta falls in the form of a white powder. To the other add a few drops of acetate of lead in solution, sulphate of lead immediately appears.

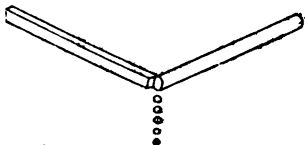
157. SULPHURETED HYDROGEN is found in a number of springs, producing the offensive odour observed in sulphureous mineral waters. It is gaseous when uncombined, and extremely noxious to animal life.

158. Mix, in a bottle with a bent tube (Fig. 19), 440 grs. of the sulphuret of iron in fragments, with 3 ounces of water and 490 grains (5 drachms by measure may be taken) of aqueous sulphuric acid. Sulphureted hydrogen escapes with effervescence,

and may be collected in jars or flasks at the pneumatic trough (Fig. 15). The sulphur of the sulphuret takes hydrogen from part of the water producing the gas; the iron takes the oxygen with which the acid produces sulphate of iron; it remains with the undecomposed water.

159. Heat a bar of iron to whiteness, at a smith's forge, and press upon the extremity a roll of sulphur, inclining them in the manner represented, and collecting under water, in any iron vessel, the red-hot fluid, which is immediately formed. It is the sulphuret of iron, very brittle when solid, and composed of 28 of iron and 16 of sulphur.

Fig. 27.



160. Invert a jar, and apply a lighted match; the gas burns, and produces sulphurous acid and water as it acts upon the oxygen of the air; part of the sulphur is not consumed.

161. Fill a flask full of water, introduce a portion of the gas till it is half full, cork it under water, lift it out with the cork downwards, shake it well, and then loosen the cork, keeping the flask in the same position; the air rushes in to supply the place left vacant as the gas unites with the water. The solution is of the same nature with sulphureous mineral waters, but much stronger.

162. Moisten carbonate of lead with water, spread it upon a piece of paper, and introduce it into a jar or flask of the gas. The carbonate is immediately blackened, the changes represented in Figs. 2. and 3. taking place.

163. Symb. S , Sulphuric Acid. H:S , Aqueous Sulphuric Acid. $\text{H:S\&SFe} = \text{S}\cdot\text{Fe}$ and HS . Water, Sulphuric Acid, and Sulphuret of Iron, produce Sulphate of Iron and Sulphureted hydrogen.

164. PHOSPHORUS.—Heat bones in an open fire, a white matter remains, composed principally of phosphoric acid and lime; by sulphuric acid the greater portion of the lime may be removed, and if the acid be now heated with charcoal, it removes oxygen, and the phosphorus is converted into vapour. This process is too complicated for beginners to attempt it.

165. Phosphorus being inflamed with great facility, it ought always to be cut under water, and never touched directly by the

fingers; it gives a very severe burn when it touches any part of the body after it has been inflamed. When used in any experiment where no water is required, it ought always to be dried previously, by placing it between folds of bibulous paper.

166. Put 5 grains of dry phosphorus upon a tin cup, supported as in Fig. 24, and placed upon a plate; inflame it, and cover it with a dry jar. The phosphorus unites with the oxygen of the air, and produces a solid acid, which falls down in the included air like flakes of snow.

167. Put 5 grains of dry and newly kindled phosphorus into a jar or flask full of oxygen, and capable of containing about 30 ounces of water; the phosphorus may be supported in a cup (Figs. 23. and 26.), and should be placed as low as possible in the vessel containing the oxygen. A very vivid light appears during the combustion of phosphorus in oxygen; an acid compound is formed, as in 125.

168. Place a thin slice of dried phosphorus (about $\frac{1}{4}$ of a grain) between folds of writing-paper, and rub it briskly with a glass-stopper. The heat produced by the friction soon inflames the phosphorus.

169. Melt 3 or 4 grains of phosphorus in a test tube, give heat till it boils for five or ten minutes, and allow it to cool. If a sulphur match be now introduced, it may be made to rub off a portion of the phosphorus, the heat produced enabling the phosphorus to take fire on coming in contact with the air.

170. Put 10 grains of phosphorus into an ale-glass with boiling water, and force oxygen gas upon it, pressing out the oxygen from a bag such as has been described (See Fig. 18). The phosphorus inflames under the boiling water.

171. Heat 30 grains of phosphorus with 30 drops of water and 30 grains of aqueous potassa in a very small retort, till a gas comes away which inflames as it comes in contact with the oxygen of the air. When the gas comes steadily away, the beak of the retort may be placed under water. Every portion of gas which rises through the water produces a beautiful wreath of smoke as it rises in the air. The gas is produced by one part of the phosphorus taking hydrogen from the water, while the rest takes oxygen and combines with the potassa. As it burns, the hydrogen forms water with the oxygen of the air, and the phosphorus also unites with oxygen.

172. Take a stick of phosphorus, holding it with pincers, and draw lines with it upon a wooden board in a dark room; whenever the phosphorus touches the wood, a portion is absorbed, which retains its luminousness for a long time.

CHAP. XII.—CARBON, CARBONIC ACID, COAL AND OIL GAS, COMBUSTION, VENTILATION.

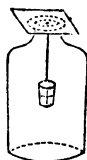
173. Carbon is found in many different forms.

- I. The **DIAMOND** is composed of pure carbon.
- II. **CHARCOAL** consists almost entirely of carbon, and is prepared by heating wood so as to expel all the gaseous matter it contains. Heat a few chips of wood in a glass tube by the flame of a lamp, or in an iron pot placed upon a common fire, so long as gas and vapour are rapidly disengaged; charcoal is left, which must be excluded from the air as it is cooled, to prevent it from taking fire.
- III. Heat common coal in the same manner; coal gas and other compounds are expelled, and the carbon is left in the form of a cinder, forming what is commonly termed **COKE**.
- IV. **LAMP BLACK** is the carbon deposited from a smoky flame.
- V. **IVORY BLACK**, or **ANIMAL CHARCOAL**, are terms usually applied to carbon in the condition in which it is obtained when bones are heated and the air excluded. A large portion of earthy matter is mixed with it in this condition.
- VI. **PLUMBAGO**, commonly called **BLACK LEAD**, is composed principally of carbon with a small quantity of iron.
- VII. **COAL** consists in general of carbon, oxygen, hydrogen, and nitrogen, and is considered to have been formed from decayed vegetable matter. Few traces of animal matter have hitherto been observed. When heated, the gases are expelled, and carry along with them a quantity of carbon, producing common coal-gas, which burns upon the coal if air be supplied to it, but may be conveyed, as in gas-pipes, to any distance if the air be excluded. Other gases are also formed.
- VIII. **SPLINT COAL** has a splintery fracture.
- IX. **CAKING COAL** fuses, and forms a cake when heated.

- X. CHERRY COAL has a slaty fracture, and is easily broken.
- XI. CANNEL COAL, or PARROT COAL, gives much gas when heated, and was formerly used instead of candles.
- XII. GLANCE COAL, or ANTHRACITE, consisting almost entirely of carbon, gives no gas when heated, but burns with a fixed light.
- XIII. BROWN COAL, BITUMINOUS WOOD, or SURTURBRAND, has a brown colour, and resembles peat.
- XIV. JET is another variety of coal; it is used in making black ornaments. NAPHTHA, PETROLEUM, MINERAL TAR, MINERAL PITCH, and MINERAL CAOUTCHOUC, are all composed principally of carbon and hydrogen, and considered as products of the decomposition of coal; substances similar to most of them being formed in preparing coal-gas.

174. Put some fragments of charcoal in a copper cup or cage; heat any of them to redness in a lamp, and introduce them into a jar, flask, or phial, containing oxygen (Fig. 28.). A brilliant combustion takes place, the charcoal burning with a fixed light. Carbonic acid gas is always formed when carbon is freely supplied with oxygen, whatever its source may be.

Fig. 28.



175. In the combustion of a common fire, where there is a thick bed of cinders, three circumstances require attention:

- I. Carbonic acid is formed below where the air first acts upon the carbon.
- II. Part of the carbon of the superincumbent red-hot cinders takes away half of the oxygen from the carbonic acid as it rises through them, and 2 particles of carbonic oxide gas are formed by the decomposition of every particle of carbonic acid.
- III. These 2 particles of carbonic oxide burn with a blue flame as they come in contact with fresh air, producing 2 of carbonic acid, as an additional supply of oxygen is communicated to them.

These changes may be thus expressed symbolically:

- I. $C + O^2 = C$. Carbon and 2 of oxygen produce carbonic acid.
- II. $2C + C = 2C$. Carbonic acid and 1 of carbon produce 2 of carbonic oxide.

III. $2\text{C} + \text{O}_2 = 2\text{C}$. 2 of carbonic oxide and 2 of oxygen produce 2 of carbonic acid.

176. In warm weather there is much moisture in the air, and the hydrogen of the watery vapour which passes through the fire produces with the carbon a gas, which changes a little the colour of the blue flame. The blue flame is best seen in very cold frosty weather, when the air contains little moisture.

CARBONIC ACID AND CARBONIC OXIDE.

177. Prepare carbonic acid gas at the pneumatic trough, using the bottle and bent tube represented in Fig. 19, introducing into it an ounce of aqueous muriatic acid previously mixed with 2 of water, and about a table-spoonful of large fragments of chalk or marble, which are composed of carbonic acid and lime; the muriatic acid unites with the lime, and carbonic acid gas escapes with effervescence. Symb. $\text{HCl} + \text{C-Ca} = \text{HCl-Ca} + \text{C}$. Two or three jars of gas may be collected, and a flask or bottle filled half full.

178. Introduce a lighted candle (Fig. 12.) into one of the jars; it is immediately extinguished.

179. Invert another jar, and leave it without any cover for five or ten minutes; then try it with the candle as before: the carbonic acid gas being heavy, remains in the jar for a considerable time.

180. Shake the bottle with carbonic acid and water, the gas is absorbed, as in 161. Add a little litmus in solution; the blue changes to a red. Boil a little of the red liquid in a flask or tube; the gas escapes and the blue is restored.

181. Carbonic acid gas is fatal to animal life: animals introduced into it immediately die. Diluted with air to such an extent that respiration may be continued, it produces headach, oppression, dulness, and inactivity. It is produced by the combustion of carbon, and by respiration; so that crowded or ill-ventilated apartments are extremely unwholesome, and sometimes dangerous, from the accumulation of carbonic acid. It is found during fermentation and putrefaction, and accumulates in old wells, pits, and caverns: before attempting to enter into any of them, a lighted oil-lamp should be introduced, and if extinguished, any one entering would probably be suffocated. A candle is often extinguished in air vitiated with carbonic acid, though a lamp may burn in it.

182. Heat 50 grains of crystallized oxalic acid in a retort with an ounce by measure of aqueous sulphuric acid. Collect the gases evolved at the pneumatic trough. The oxalic acid is decomposed and resolved into carbonic acid and carbonic oxide gases, as the hot sulphuric acid removes its water of crystallization. Symb. $;\text{C}^2 = :\text{C}\&\cdot\text{C}.$

183. Invert a jar of the mixed gases, and pour into it as much lime-water as will fill it about 1-3d full. Shake the lime-water with the gases, keeping on the cover of the jar; carbonic acid gas is condensed, producing carbonate of lime, which renders the liquid milky. Inflamm the remaining carbonic oxide; it burns with a blue flame.

COAL AND OIL GASES.

184. When coal, oil, tallow, wax, resin, and many other inflammable substances, are exposed to heat, gaseous compounds of hydrogen and carbon are produced in large quantity. In an open fire, the gas burns as it escapes from the coal, &c; and an oil-lamp or tallow candle may be compared to a small gas manufactory, where the gas is consumed by the air as it is produced upon the wick.

185. Heat by a lamp some fragments of coal in a small test tube; gas is expelled, which may be inflamed. Water charged with ammonia, and a tarry matter; may also be seen as the heat is continued; coke is left in the tube.

186. When coal contains sulphuret of iron, sulphureted hydrogen gas is also formed, which is removed by lime.

187. The gaseous compounds of hydrogen and carbon are usually called CARBURETED HYDROGEN GASES. The more they abound in carbon, the richer the flame they produce as they burn. HYDRURET OF CARBON is more valuable than the BIHYDRURET, and is found in larger quantity in oil than in coal gas. Their composition may be seen in the table, page 8.

188. The products of the combustion of carbureted hydrogen gases are carbonic acid and water, the nitrogen of the air being separated.

189. Hydruret of carbon acts on 3 particles of air; carbonic acid and water are formed, and 6 of nitrogen separated. Symb. $\text{HC}\&3\cdot\text{N}^2 = :\text{C}\&\cdot\text{H}\&6\text{N}.$

190. Bihydruret of carbon consumes 4 particles of air, producing 1 of carbonic acid and 2 of water, 8 of nitrogen being detached. Sym. $\text{H}^2\text{C}\&4\cdot\text{N}^2 = \text{C}\&2\cdot\text{H}$ and 8N .

Fig. 29.

191. The flame of a common lamp or candle is produced by the gas formed around the wick acting upon the oxygen of the air; it is confined solely to the exterior portion of the ascending gas. In Fig. 29, *aa* denotes the part in a state of combustion. All without is merely heated air, or the products of combustion; and all within is unconsumed gas, rising in its turn to affect the oxygen of the air.



192. If a glass-tube be introduced within the flame of a large lamp or candle, in the manner represented in Fig. 30, part of the unconsumed gas passes through it, and may be kindled as it escapes. With a tube 1-4th of an inch in diameter, and a foot long, this is very easily shewn; the wider the tube the better, if the flame be sufficiently large.

Fig. 30.

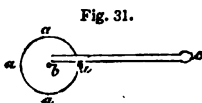


Fig. 31.

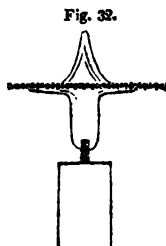


Fig. 32.

Fig. 31. shews a section across the flame, with the position of the tube.

193. The nature of flame is beautifully illustrated by holding over the flame of a candle, or of a large stream of gas, a piece of wire-gauze 6 or 8 inches square, with about 1000 meshes in the square inch. The flame is intercepted, and appears only below the gauze, a tube of flame appearing expanded as it reaches the gauze. The unconsumed gas rises through the gauze, and if a lighted match be applied, it burns on the upper side; the appearance is then presented as seen in Fig. 32.

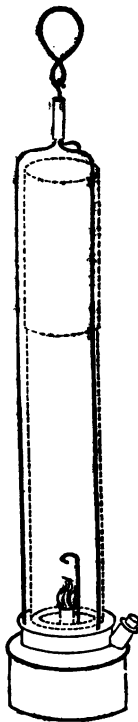
194. A white heat is required to cause the combustion of common gaseous matter in most cases with flame, and an intense heat is equally produced by the combustion of gas with flame. If flame be produced on one side of wire-gauze with small apertures, the metallic wires of the gauze being always kept cold by the surrounding air, any burning gaseous matter coming in contact with it is so much cooled, that it soon ceases to burn, and is incapable of inflaming unconsumed gas on the other side, after it shall have passed the gauze.

195. Fig. 33. represents the miner's safety-lamp, invented by Sir H. Davy, where a common lamp is surrounded with wire-gauze. In coal-mines, the atmosphere frequently becomes explosive, from the large quantity of bihydruet of carbon, the FIRE-DAMP of miners, which escapes from the coal as it is worked, and a lighted candle would instantly detonate the mixture. But with this lamp, though the explosive mixture may enter within the gauze and burn there, the flame within cannot set fire to the explosive mixture without, so that the miner has time to escape.

196. The intensity of light produced during the combustion of any gaseous matter, depends much upon the manner in which the gas is consumed. In producing a highly luminous flame, attention should be paid to the following circumstances:

- I. The combustion must be made to take place in such a manner, that an intense heat is produced.
- II. The gas, as yet unconsumed, is decomposed by the heat, and much solid charcoal is separated and suspended in the flame for an instant.
- III. This charcoal must be intensely heated, so as to be consumed. Any unconsumed charcoal gives a yellowish tinge to the flame, and, if in large quantity, is deposited ultimately in the form of soot.

Fig. 33.



197. In an argand burner, fig. 34, the intensity of the heat is augmented by causing air to enter in the middle of a circular wick or series of gas jets, so that more gas is consumed within a given space than in the ordinary manner. Thus, in Fig. 35, a section of the argand burner Fig. 34, it will be seen that the surfaces of the burning gas *aa*, *aa*, are very near, so that the interposed gas is heated much more than when these surfaces *aa* are distant, fig. 29. Much carbon therefore is precipitated, and becomes intensely luminous before it is consumed.

Fig. 34.

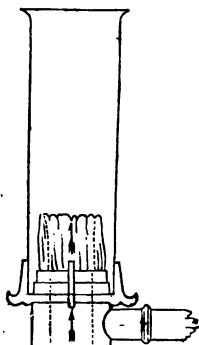
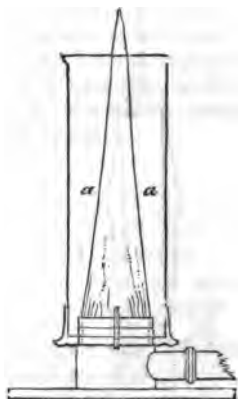


Fig. 35.



Fig. 36.



198. If the aperture by which air is admitted into the interior of the flame be closed by a piece of paper, the flame represented in Fig. 34. immediately assumes the form shewn in Fig. 36; part of the supply of air being cut off, it extends farther into the air before it meets with the oxygen necessary for combustion. The heat is accordingly diffused over a larger surface, and becomes less intense; *a* and *a* are more distant from each other; a smaller quantity of carbon is deposited, less gas being decomposed, and even that which is separated being less intensely heated, much of it is unconsumed, and produces a dingy and imperfect flame.

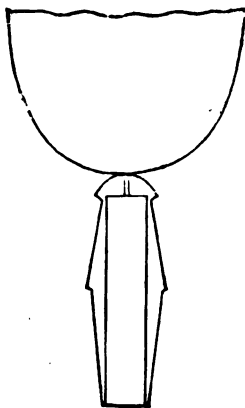
199. The most perfect form of burner is seen in the flat gas jet, Fig. 37, where two opposing currents of gas meeting each other, flash into an extremely thin sheet of gas, which extends in

an opposite direction to the currents which produce it. Fig. 38. is a section of the same jet, the side of the flame being turned towards the eye. Here, the gas on one side being so extremely near that on the other, all the conditions are fulfilled which are necessary for intense heat and light.

Fig. 37.



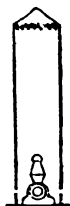
Fig. 38.



200. For some purposes where gas is used, it escapes with too much force to be employed conveniently, as in experiments with the blowpipe. By placing over it a small brass tube, Fig. 39. covered with wire-gauze, a better flame for this purpose is procured.

Fig. 39. Fig. 40.

201. If air be mixed with gas before it is inflamed, as by allowing it to rise in a tin chimney, to which the air has free access on every side, wire-gauze being placed over the top of the chimney, a flame is produced which is not more luminous than that of a spirit of wine lamp, and produces no smoke. Fig. 40. illustrates the arrangement adopted. It is easy in this way to procure a flame from an inch to a foot in diameter. Burners of this kind have been much used of late for the steady application of heat, both for domestic purposes and in the laboratory of the chemist.



202. Fig. 41. represents the roasting burner, in the manner it is manufactured by Mr Milne of this city ; it consists of a circular tube, from which numerous jets of gas escape, the meat being placed upon the upright spit in the centre.

FURNACES, FIRE-PLACES, VENTILATION.

203. If a fire be kindled in the middle of a room, Fig. 42, the door, windows, and chimney, being completely closed. the air at the fire-place expands, and becomes lighter, bulk for bulk, than the rest, which descends and flows under it, pushing it upwards in the same manner as water poured into any vessel with a cork at the bottom, sinks under the cork, and floats it as it insinuates itself below it. A perpetual circulation thus goes on so long as the heat is continued, all the air being in time involved in this movement, cooling and sinking on the exterior, while fresh quantities are continually expanding as the heat affects them.

Fig. 41

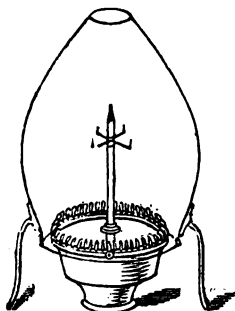
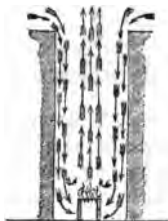


Fig. 42.

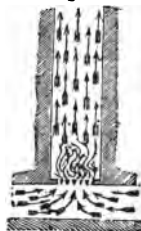


Fig. 43.



204. If a fire be kindled in an apartment or chimney, close below but open above, a current of warm air will ascend, the cold air descending at the sides and forcing it up, so that the air will be continually renewed ; see Fig. 43.

Fig. 44.

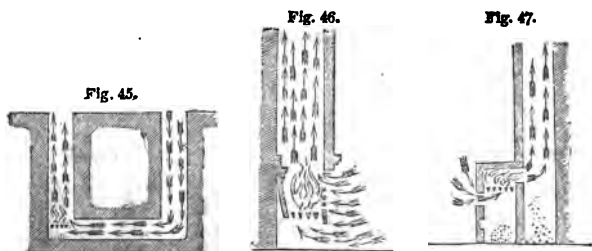


205. When a fire is heated in a chimney open below and above, the air moves quickly, the warm air in the chimney being pushed up rapidly by the external cold and heavier air, Fig. 44.

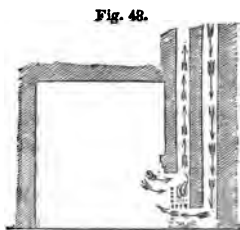
206. When two chimneys are connected together by a flue, Fig. 45, and a fire kindled in one of them, the air ascends in the one with the fire, being pushed upwards by the cold air which descends through the other. A similar arrangement is adopted in ventilating numerous mines; the horizontal part of the figure may represent that part of the mine which is worked, and the perpendicular portions the two shafts which lead to the mine, the air descending in one and rising in the other.

207. In Fig. 46, the currents are represented as they occur in a common fire-place. Air enters by the doors or windows.

208. Fig. 47. illustrates the currents in a furnace. There, the space left open in a common fire-place being closed, a more intense heat is produced, as no air escapes into the chimney, which does not pass through the fuel and contribute to the combustion.



209. Wherever air continues to escape, fresh air must have free access to the apartment. When the doors and windows fit so tightly as not to admit of this, then some aperture must be made for this purpose alone. Fig. 48. represents a mode which has been occasionally adopted for this purpose, one chimney leading in a descending current of fresh air, while by the common chimney it is carried away.



210. When air is not admitted by this or some other arrangement, cold air descends in the chimney, entangling and carrying down some of the ascending warm and smoky air, and in such cases

the room will necessarily smoke, two currents may be seen in such vents, Fig. 49, which are perpetually affecting each other.

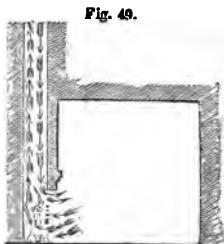


Fig. 49.

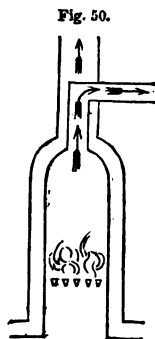


Fig. 50.

211. In stoves, Fig. 50, heated air is produced frequently by allowing cold air to enter between the inner case containing the fuel and the outer case; the air is warmed as it passes, and may be conveyed by pipes to a distant apartment. The smoke is led into a chimney by a separate tube.

212. If heated air be introduced by thousands of small apertures in the floor of any apartment, from a chamber where it is previously heated to the required temperature, it will ascend in a continuous stream when the external air is colder and heavier, as in Fig. 51. But in warm weather the currents would not be so much under control, as the air in the interior might then be frequently of the same temperature, or even colder than the air in the exterior.

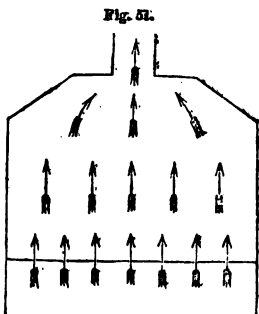
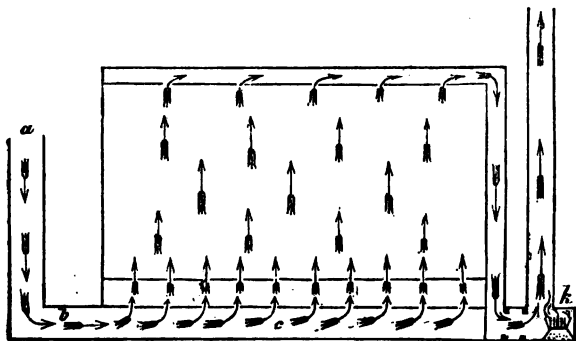


Fig. 51.

213. Large public buildings might be ventilated in the manner represented in Fig. 52. The air in the chimney having been heated powerfully and expanded much by the furnace *k*, cannot oppose the colder air in the apartment, which accordingly presses it

upwards and is forced in the same course in its turn: fresh air accordingly descends in the other chimney, as by *a*, *b*, *c*, passes

Fig. 52.



through the apertures in the floor, and rises in a slow but constant stream to the roof, whence it is conveyed to the chimney. Doors are placed so as to allow the rapidity of the current to be regulated according to the quantity of air required. A power may thus be obtained capable of operating to any extent, and so completely under control that it can be adapted to the varying circumstances in which it may be applied, while it can also be easily regulated, and diminished or increased in an instant with the utmost precision. It will also act upon air whether it may have previously been heated or cooled within the whole ranges of temperature observed at the surface of the earth, where no unusual circumstances present themselves.

214. In a common fire-place, heat is communicated principally by radiation, the smoke and consumed air ascending in the chimney. The less the quantity of metal, the greater the heat projected into the room. With large metallic bars and plates a great quantity of heat is continually withdrawn by conduction, as the air which passes by them ascends in the chimney. Sometimes polished brass plates are used with advantage at the sides of particular fire-places, to reflect into the apartment any radiant heat which may fall upon them. Grates are almost invariably placed

too high; and branders supporting the fire should be on a level with the floor, and the ash-pit sunk below them.

215. The term draught is usually employed in reference to chimneys; and when air passes through them quickly, they are said to draw well. The movement of the air depends, however, upon the colder and heavier air meeting with less resistance than before from the expanded and lighter air in the chimney; and the greater the difference between the specific gravity of the external air and that in the chimney, the more rapidly does the movement go on, or, in common language, the better does the furnace draw.

216. Figs. 53. and 54. represent some of the principal flues and furnaces attached to the large chimney in the centre of my class-

Fig. 53.

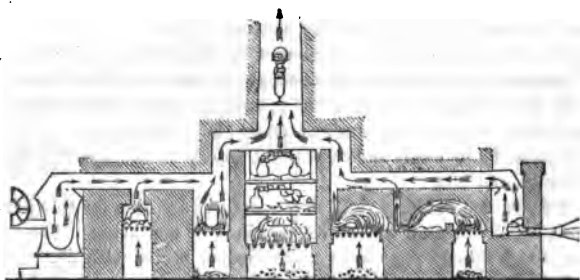
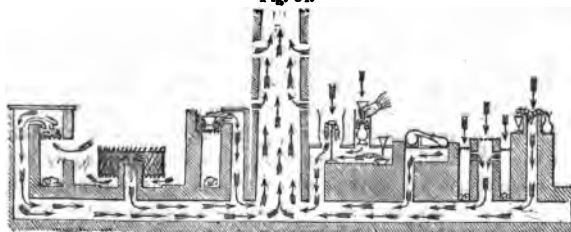


Fig. 54.



room, and the manner in which they enter in on every side, above and below ground. In some extensive manufacturing establishments from 100 to 200 furnaces often play into a single chimney.

217. To the right in Fig. 53. a SMITH'S FORGE is first observed, then a REVERBERATORY FURNACE where the flame dashes over the material to be heated, and then another furnace for miscella-

neous operations. Below, and in the middle, a furnace is placed to heat the superincumbent iron sand-bath plate, evaporating basins being put there, while noxious fumes are carried away by the aperture represented. Above is another plate of a similar form, from which a more moderate heat is procured. A glass is also represented resting on a projection, and before an aperture in the chimney, so that offensive gases from it are rapidly withdrawn. To the left, the first furnace observed is used for operations where an intense heat is required; the large open space above the fuel allows all the consumed air to escape with rapidity, and fresh air to enter. A furnace with an earthen vessel called a Muffle is next seen; it is used in refining gold and silver. A blast furnace for melting iron is observed at the extreme left; the air, instead of entering through furnace bars, being propelled by a fanner turned two thousand times a minute by a steam-engine.

218. In Fig. 54. another section of the same chimney is shewn, illustrative of the arrangements adopted in several of the furnaces with descending flues, and of the manner in which fumes are carried off in numerous operations where the phenomena could not otherwise be so easily shewn without injury to the operator and those around him.

219. On the extreme right four apertures are seen for this purpose, which are used with different kinds of apparatus. The retort which follows rests upon a few cinders mixed with charcoal, the air descending as in the other flues, while the receiver is kept cold by the rapid current of air descending on every side. In the next figure the experimenter is supposed to be introducing antimony or arsenic into a vase of chlorine surrounded by a glass chimney, and adjoining the chimney there is a large glass ventilator used for numerous experiments; naphtha is represented burning in a cup, the flame descending upwards of 12 or 18 inches. On the left hand, two furnaces are seen, well adapted for shewing some crucible operations which require to be watched as they advance, and between them is observed a section of the circular fire by which the practical class room is heated; it is about 3 feet in diameter, with a circular vent in the middle, about 10 inches in diameter, which carries away the products of combustion; with a less powerful chimney than that into which it plays, the diameter of the vent would require to be 2 or 3 inches greater. Coke is usually employed in this fire-place, and the chimney is generally concealed from view by a wreath of blue flame, which descends

within it, being produced by the combustion of carbonic oxide formed as described in 196.

220. If a single furnace be required, perhaps none will be found more generally useful than that represented in Figs. 13. and 14. Another form is sometimes adopted, Fig. 55, where it is not necessary to adapt it for iron bottles with attached tubes for the preparation of oxygen and other gases; if the flue be carried from 10 to 20 feet high, or be led into another chimney, it produces great heat. The numbers express the size in inches.

Fig. 55.

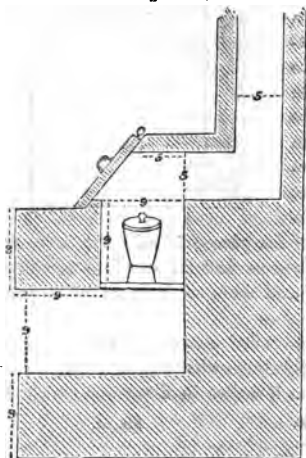
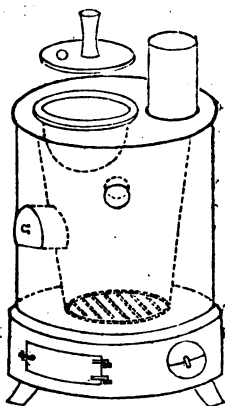


Fig. 56.



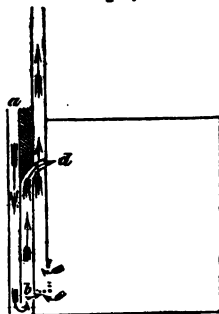
221. Dr Black's portable furnace, Fig. 56, is much used, and consists of a case of stout sheet-iron lined to the thickness of 2 or 3 inches with a very infusible clay or earthy composition. Above is an aperture for an iron-pot to contain sand, and other openings may also be observed for introducing tubes and different kinds of apparatus. The pipe carrying away the smoke must be prolonged, or connected with a chimney.

222. Dr Arnott lately shewed that three-fourths of the heat produced in a common fire-place is wasted or carried away by the chimney, and has proposed to employ an earthen-ware furnace inclosed in an iron box, so that a much larger portion of heat shall be obtained from the fuel, apertures being made in the iron cham-

ber to regulate the currents of air. A great saving of fuel has been effected in this manner.

223. In the arrangement adopted by Mr Adams of Falkirk for heating any apartment, the fuel is economized, and the ventilation effectually secured. Cold air descends by *a* (Fig. 57), and is heated by coming in contact with the back of the grate in the air chamber *b*; from it a small portion is allowed to enter near the fire by numerous openings, and the rest passes into the apartment along the floor; or, where this cannot so conveniently be done, it may be introduced above as at *d*, or at a little distance from the chimney. It is obvious, however, that it is not necessary that any of the air should pass directly from the air-chamber to the fire-place; if all of it be made to pass into the room, it must soon find its way into the fire-place, from the expansion produced there as the combustion proceeds.

Fig. 57.



224. Small portable furnaces, called **CHAUFFERS**, are found very convenient in numerous operations where heat is required; they may be made from 3 to 6 or 8 inches in diameter, and 6, 8,

Fig. 58.

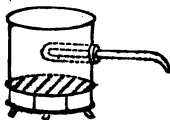


Fig. 61.



Fig. 58.

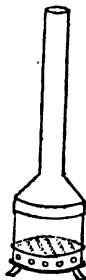
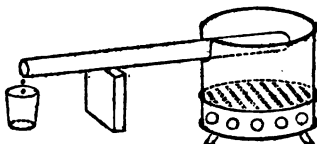


Fig. 59.

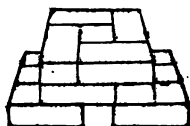


or 10 inches deep. A chimney put over them increases the heat, Fig. 58. Tubes are often heated with them in the manner shewn in Figs. 59. and 60. Occasionally small crucibles are perforated and used as chauffers. Fig. 61.

225. Chauffers are usually filled with red-hot cinders or charcoal. Wood heated in a common fire till all flame ceases, gives excellent charcoal for this purpose. When the chauffer is very small, charcoal alone is employed.

226. With 20 or 24 bricks, and a few small slips of narrow hoop iron, a chauffer or small furnace may be constructed in a few minutes, capable of giving a good red heat, where the usual facilities for operating are not to be obtained, and where a common fire is not accessible. Suppose the bricks to be 5 inches broad and 10 long, 3 are laid side by side as in Fig. 62, and 3 more in the same way, and opposite to the first, at the distance of 4 inches. The slips of iron are placed in the middle to support the fuel, and one or two courses of bricks laid above them, so as to leave an aperture 5 inches square. If the bricks be laid with mortar or clay, the current of air will be still stronger, and the heat greater. By using small pieces of charcoal, the heat may be moderated so as to be employed with flasks and retorts, as well as crucibles.

Fig. 62.



227. In all cases where a strong heat is required, all apertures leading into the chimney above the place where the fuel rests ought to be closed, and any of the apertures leading into the chimney from any furnace not in use must also be shut, otherwise cold air rushing in by them reduces the temperature of the warm ascending current, and consequently reduces also the temperature in those furnaces in use, by preventing so rapid a consumption of the fuel.

228. Where many furnaces play into one chimney, if it be not sufficiently large, only part of them ought to be used at the same time.

229. If the smoke from a common fire be not carried up the chimney, and if there be sufficient air allowed to enter by the doors or windows, then, by closing the aperture between the top of the fire and the chimney, so that no air can have access to it except through the fuel, the smoke may in general be prevented from returning.

230. All furnaces where a steady and regulated temperature is required, must be provided with ash-pit doors, by which a fixed and steady supply of air can be admitted, and regulated so as to produce a powerful or moderate heat. But cutting off altogether the supply of air, the fuel may be kept unconsumed for any length of time.

CHAP. XIII.—CHLORINE.

231. Chlorine is a greenish-yellow coloured gas, formerly called OXYMURIATIC ACID. It has a pungent suffocating odour, acts with great energy on metals, and numerous inflammable substances abounding in hydrogen; all vegetable and animal colouring matters, and offensive effluvia from decomposed animal or vegetable matter, are quickly destroyed by it. Experiments with chlorine and its compounds should be performed so that all the noxious fumes may be carried away.

232. Heat cautiously in a retort 1 ounce of binoxide of manganese in fine powder, with 3 ounces by measure of aqueous muriatic acid; put the acid first into the retort. Collect the chlorine gas at the pneumatic trough (see 107), having heated the water previously to 90; chlorine is condensed by cold water. Remove the retort when the gas comes slowly away, to prevent accident from regurgitation.

233. Muriatic acid consists of hydrogen and chlorine, and two particles of it with one of binoxide of manganese produce chlorine gas, water, and muriate of manganese, which remains in the retort. Symb. $2\text{HCl} \& \text{Mn} = \text{Cl} \& \text{H} \& \text{HCl} \cdot \text{Mn}$.

234. If a jar of chlorine be required quickly, put a table-spoonful of chloride of lime (common bleaching powder) into it, and pour upon it an equal bulk of aqueous muriatic acid. The muriatic acid unites with the lime, and displaces the chlorine; it is not procured sufficiently pure in this way for some experiments.

235. Kindle a suspended candle, and introduce it into a jar of chlorine; it attracts hydrogen from the inflammable matter, carbon is separated, and the candle burns with a lurid flame.

236. Into a detonating jar, 2–3ds full of chlorine gas, introduce coal-gas till it is filled, invert quickly and apply a light; an explosion ensues, the chlorine takes hydrogen from the gas, produces muriatic acid, and carbon is deposited.

237. Mix equal bulks of chlorine and hydrogen gases in a de-

tonating jar, and apply a light; they combine with explosion, and produce muriatic acid gas.

238. Pour antimony in powder through a funnel into chlorine gas; it takes fire as it combines with the chlorine.

239. Introduce copper-leaf suspended in an iron cage into another jar; it also evolves heat and light as it combines with the chlorine.

240. Make a solution of chlorine in water, proceeding in the manner described in 161.

241. Add a portion of the solution to water tinged with vegetable blue; it is immediately bleached, the chlorine decomposing the colouring matter by taking hydrogen from it.

242. CHLORATE OF POTASSA, composed of chloric acid and potassa, is formed by the action of chlorine, water, and potassa; the chloric acid consists of chlorine and oxygen, and both these elements are separated from the chlorate in numerous experiments.

243. Put a tea-spoonful of powdered chlorate of potassa into an ale-glass, cover it with aqueous muriatic acid. A deep green-coloured gas is evolved, composed of chlorine mixed with a gaseous compound of chlorine and oxygen; paper, previously dipped in oil of turpentine, is immediately inflamed in this gas.

244. Into another ale-glass, put a tea-spoonful of the crystals, after filling it with cold water, and throw upon them five or six chips of phosphorus, each about the size of a pea. Fill a pipette, Fig. 63, with aqueous sulphuric acid, allowing the acid at first to drop through it, that all air may be expelled; then leave it in the glass, the extremity resting upon the crystals of the chlorate. As the acid slowly descends, it takes potassa from the salt, and disengages a compound of chlorine and oxygen, which inflames the phosphorus under water.

Fig. 63.



245. Triturate briskly in a mortar half a grain of chlorate of potassa with as much sulphur; it quickly takes oxygen from the chlorate, producing an explosion.

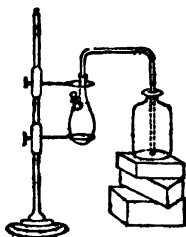
246. All these experiments must be cautiously performed; the gaseous compound of chlorine and oxygen explodes violently when gently heated. Many accidents have occurred from mixing chlorate of potassa and aqueous sulphuric acid in tubes and retorts.

247. MURIATIC or HYDROCHLORIC ACID is a gas (see page 8),

which is condensed in large quantity by water, forming the common aqueous muriatic acid, and often termed **SPIRIT OF SALT**.

248. Heat strong aqueous muriatic acid as it is obtained from the manufactory; muriatic acid gas is expelled from it, and may be collected in a flask or bottle as shewn in Fig. 64. When full of gas remove the tube, close the mouth by the thumb, and place it, with the mouth downwards, under water coloured by vegetable blue; on removing the thumb the water is forced with great rapidity into the bottle by the pressure of the air as it combines with the gas, the vegetable blue being reddened.

Fig. 64.



249. Mix 2 drams by measure of aqueous sulphuric acid in a flask with an equal bulk of water; when cold, pour it upon 200 grains of common salt in a retort, and apply heat, introducing the beak of the retort into a receiver 1-3d full of water, which must be kept cold; the beak of the retort should not be placed under the water. The sulphuric acid causes a decomposition of the common salt, which is composed of chlorine and sodium, and of the water; chlorine from one and hydrogen from the other produce muriatic acid gas, which is condensed by the water in the receiver. Sulphuric acid and soda, composed of sodium and the oxygen of the water, remain in the retort, forming sulphate of soda. Symb. $!S\&ClNa\&H = !S\&Na\&HCl$.

250. Mix aqueous nitric and aqueous muriatic acids in a flask, and apply heat. Oxygen from the nitric and hydrogen from the muriatic acid combine and form water, nitrous acid and chlorine are then set at liberty. Symb. $!N\&HCl = !N\&H\&Cl$.

This mixture is termed **NITROMURIATIC ACID**, and also **AQUA REGIA**, as it dissolves gold; it is much used in dissolving metals when chlorine is required.

251. Add a solution of nitrate of silver to a solution of chlorine or common salt in water, or to diluted muriatic or nitromuriatic acid; a white curdy-looking compound immediately falls, composed of chlorine and silver; it assumes a dark tint when exposed to the light, and is termed **Chloride of Silver**.

252. Iodine, bromine and fluorine are similar in their general properties to chlorine, but not so important.

253. Heat a few grains of iodine in a flask; a beautiful violet-coloured vapour is observed, which condenses slowly in crystals.

254. Mix a solution of starch with a solution of iodine in water; a blue compound appears—the iodide of starch. Put a little into a flask, and pour boiling water upon it till the colour disappears; immediately afterwards pour it into cold water and the colour is restored.

255. Iodine is obtained from sea-ware, after subjecting it to a number of complicated processes. A compound of iodine and potassium is much used for medicinal purposes, and in testing several metals.

256. Add a few drops of a solution of the iodide to starch; no effect is produced. Add to the mixture a drop of chlorine water or of aqueous sulphuric acid to detach the iodine; it immediately produces the blue iodide of starch.

CHAP. XIV.—METALS.

257. Metals are seldom obtained in a pure form in nature; they are generally combined with oxygen, sulphur, or chlorine, and often also with sulphuric, nitric, carbonic, and phosphoric acids. In preparing them from the minerals in which they occur, they are said to be REDUCED from their ORES. Charcoal is employed to take away oxygen; and lime, carbonate of potassa or soda, or iron, to remove sulphur and chlorine. Where there is much earthy matter mixed with the ore of a common metal, alkalis, glass, or other earths are added, so as to form a fusible compound with them, through which the metal may fall; the substance added is usually called a FLUX, as it promotes the flowing or melting of the different ingredients which might otherwise prevent the particles of the metal from running together.

258. Métaux are distinguished by their peculiar lustre and opacity; many of them are very malleable and ductile, being easily extended into thin leaves or drawn into fine wire. They are good conductors of heat and electricity, unite with many non-metallic bodies, when they lose in general all their lustre, and assume an earthy appearance.

259. Compounds of metals with oxygen, chlorine, and iodine, are termed Oxides, Chlorides, and Iodides. With sulphur, phosphorus, and carbon, the compounds are termed Sulphurets, Phosphurets, and Carburets. When an acid, the name of which termi-

nates in *ic*, unites with an oxide, the name of the acid in the compound is made to terminate in *ate*. Thus, nitric acid uniting with potassa produces nitrate of potassa.

260. The metals are divided into three great classes :—

- I. **KALIGENOUS METALS**, which produce alkalies when combined with oxygen.
- II. **TERRIGENOUS METALS**, which form earths of different kinds as they combine with oxygen.
- III. **CALCIGENOUS or COMMON METALS**, whose oxides have long been called **CALCES**.

CHAP. XV.—POTASSIUM, POTASSA, NITRATE OF POTASSA.

261. The most important kaligenous metals are potassium and sodium, which, with oxygen, form potassa and soda. These have been termed **FIXED ALKALIS**, as they are not easily converted into vapour, but ammonia, the volatile alkali, is a gas at natural temperatures. The alkalies turn vegetable blue to green, yellow turmeric to a reddish-brown, corrode animal and vegetable substances, and form soaps with oily and fatty substances.

262. **POTASSIUM** is procured from potassa, by heating it powerfully with charcoal or iron; the process requires much attention; none who are not well acquainted with chemical manipulation should attempt to prepare it.

263. Throw a grain of potassium upon water; it takes fire and burns upon the surface of the water; potassa is formed, which is quickly dissolved.

264. Boil, in an iron goblet, 1 pound of newly slaked lime, in fine powder, with an equal weight of carbonate of potassa and 10 pounds of water; the carbonic acid unites with the lime, the potassa is left in solution. Put the mixture into an earthen or glass funnel, obstructed by a few fragments of glass and a piece of linen cloth; collect the solution in bottles as it escapes, drop by drop. Exclude it during its preparation, and afterwards, carefully from the air, otherwise the potassa attracts carbonic acid.

265. Fused potassa (common caustic) is procured by evaporating the solution, and fusing by an increased heat the dry matter that remains.

266. Add a solution of potassa, of the carbonate of potassa, or of the bicarbonate, to water tinged with vegetable blue. A fine

green is perceived. Add, drop by drop, aqueous sulphuric, nitric or muriatic acid, to the green liquid; the acid combines with the alkali, and the blue colour is at last restored. Similar experiments may be performed with other acids.

267. The quantity of potassa in pot-ashes or pearl-ashes is ascertained by the action of acids; every 49 grains of aqueous sulphuric acid required to restore the blue colour in a solution of the alkali tinged by the colouring matter of the cabbage, indicating 48 of potassa = $K+O$. As acids and alkalis combine, they lose their causticity as well as their power of affecting vegetable colours, and are said to NEUTRALIZE each other.

268. Burn a few small pieces of wood, collect the ash that remains, pour water upon it, and add vegetable blue. Potassa is found in solution, which turns the blue to a green. The pot-ashes of commerce are prepared from the ashes of burned wood.

269. Expose pearl-ashes (impure carbonate of potassa) to the air in a cup or plate; they soon deliquesce. (See 32.)

270. Heat an ounce or two of nitre in a crucible; it soon melts, and if heated much, oxygen escapes, but no combustion is observed. Pour upon it while red hot small successive quantities of sulphur and charcoal in fine powder, avoiding the fumes; the charcoal and sulphur burn quickly as they receive oxygen from the nitre.

271. Throw some nitre upon red hot cinders; they burn with great rapidity.

272. Dissolve nitre in boiling water, so long as any is taken up; crystals of nitre in six-sided prisms appear as the solution cools.

273. Dip paper into the solution which remains above the crystals, dry it, and apply a light; it burns quickly, in the same manner as common match paper.

274. Mix intimately 75 grains of nitre, 15 of sulphur, and 10 of charcoal. The mixture deflagrates like GUNPOWDER when heated; machinery is required to give it the granular appearance of gunpowder.

275. Mix 600 grains of nitre, 200 of sulphur, and 100 of sulphuret of antimony. This mixture is termed the blue signal light, which is seen, when inflamed, at a great distance.

276. Nitre occurs in the soil in India, and is also formed artificially. In all deflagrating mixtures containing nitre, oxygen is rapidly transferred from the nitric acid to the inflammable matter.

277. Heat BITARTRATE OF POTASSA (CREAM OF TARTAR), con-

sisting of tartaric acid and potassa, in a crucible; it is soon blackened, as the tartaric acid is decomposed. A small quantity held on a slip of glass presents the same appearance. Water poured upon the black matter dissolves the potassa; it may be tried by the vegetable blue, which becomes green as before.

278. Heat in the same manner equal weights of cream of tartar and nitre; the potassa of both remains united with carbonic acid, which is formed as the carbon of the tartaric acid unites with oxygen from the nitric acid in the nitre. In this manner very pure carbonate of potassa is formed.

279. Add a solution of tartaric acid to a strong solution of any salt of potassa; crystals of cream of tartar soon appear. Cream of tartar is usually procured from the juice of the grape, being deposited in crystals.

CHAP. XVI.—SODA.

280. Soda = sodium 24 + oxygen 8. Sodium and soda are similar to potassium and potassa in all their leading properties. Soda is obtained principally from common salt and aqueous sulphuric acid, when the changes described in 242. take place. The sulphuric acid is withdrawn afterwards, and replaced by carbonic acid on heating the sulphate of soda with charcoal and chalk. Water dissolves the carbonate of soda, which is then crystallized, forming the compound usually termed soda.

281. KULP and BARILLA are the ashes that remain after burning sea-ware. Soda has long been extracted from them by the action of water.

282. CHLORIDE OF SODIUM or COMMON SALT = 36 chlorine + 24 sodium = 60. When procured by evaporating sea-water slowly by the action of the sun in warm climates, after allowing it to overflow fields from which the sea is afterwards excluded, it is termed BAY-SALT. PAN-SALT is obtained by boiling rapidly sea-water in an iron pan. ROCK-SALT is the term applied when it is dug out of salt mines, many of which are found in different parts of the globe of great extent, and containing often very pure salt.

283. Common salt crystallizes in cubes, which are often associated so as to form hollow pyramids.

284. Throw some crystals of bay-salt upon a red hot plate of iron, they fall in pieces quickly with a loud decrepitating noise;

the experimenter must avoid the fragments as the crystals break.

285. Dissolve common salt in boiling water, and add a solution of carbonate of soda; if common salt be pure no effect is seen, but if any magnesia be present it soon appears as a white powder.

286. When magnesian salts are mixed with common salt, which is often the case, it is very apt to attract moisture, and acquires a bitter disagreeable taste; it is also much less fit for curing meat.

287. BICARBONATE OF SODA or BORAX contains two particles of boracic acid and one of soda, with water of crystallization. Heat 200 grains in a crucible capable of holding 800; the water is expelled; the dry borax is fused into a transparent and colourless glass.

288. Mix a tea-spoonful of powdered borax with an equal bulk of aqueous sulphuric acid in an evaporating basin, add half an ounce of alcohol. Heat the mixture and kindle the alcohol; the sulphuric acid unites with the soda, and the alcohol burns with a beautiful green flame, in consequence of the presence of the boracic acid.

CHAP. XVII.—AMMONIA. *

289. Ammonia 17 = nitrogen 14 + 3 hydrogen = NH_3 . A gaseous compound, alkaline like potassa, and often termed spirit of hartshorn, being formed when the horn of the deer and most animal substances are heated, the air being excluded; it is also formed in large quantity during the preparation of coal-gas. It is usually combined with muriatic acid, from which it is separated again by lime, to prepare it free from the offensive odour of animal matter, which at first it always presents. Being condensed in large quantity by water, it is usually employed in combination with this substance.

290. Heat half an ounce of strong aqueous ammonia in a small flask, receiving the gas, which is lighter than air, in another flask, as in Fig. 65. The air is soon expelled, and then the flask must be removed, proceeding as described in 248. The coloured water is forced with great rapidity into the flask by the pressure of the air as the ammoniacal gas combines with it, and immediately becomes green.

291. Put a dram of strong aqueous muriatic acid into any flask,

* Ammonia is inserted here, though it contains no metallic matter, as it is very similar to the alkalis in most of its properties.

vase, or bottle, and a dram of strong aqueous ammonia into another, then connect them by a tube passing through a cork which fits the bottle, Fig. 66. White fumes of muriate of ammonia, or sal-ammoniac, immediately appear.

Fig. 65.

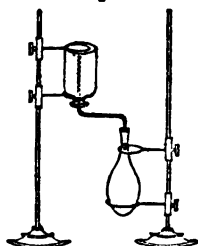
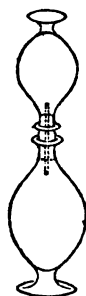


Fig. 66.



292. If no apparatus peculiarly adapted for the preparation of ammonia can be procured, mix 150 grains of muriate of ammonia with 100 of slaked lime in fine powder; heat the mixture in a glass retort by a lamp or chauffer, and condense the gas in a receiver half full of water. Shake the receiver frequently, but always keep the beak of the retort out of the water.

293. Hold test papers above aqueous ammonia; the ammoniacal gas escaping from the aqueous ammonia affects them in the same manner as potassa. Expose them to a very gentle heat, the ammonia is expelled, and the original colour is restored.

294. Prepare sulphureted hydrogen gas in a phial with a bent tube, Fig. 67, passing the gas into an ounce of common aqueous ammonia contained in another phial; a large quantity combines with the ammonia; the solution is now termed HYDROSULPHURET OF AMMONIA, and is often much used instead of sulphureted hydrogen gas in testing metals.

Fig. 67.



295. Dissolve oxalic acid in water, and add carbonate of ammonia till the solution no longer reddens the blue test-paper; the oxalic acid unites with the ammonia in the carbonate, expelling the carbonic acid with effervescence.

296. Heat a little of any salt suspected to contain ammonia

with an equal bulk of slaked lime in a test-tube; ammoniacal gas is expelled if any be present, and may be recognised by its odour, or by the white fumes it produces when brought in contact with a rod dipped in muriatic acid. Soda or potassa may be used instead of lime.

CHAP. XVIII.—LIME, PLASTER OF PARIS.

297. Earths are composed of metals and oxygen, in the same manner as the alkalis, potassa and soda; four of them, lime, baryta, strontia, and magnesia, resemble alkalis, but they are not fused by heat, they are less soluble in water, less caustic, and form insoluble compounds with carbonic acid.

298. LIMESTONE, CHALK, MARBLE, and CALCAREOUS SPAR, are composed principally of carbonic acid and lime, and are called CARBONATES OF LIME. Heat a few fragments of limestone or marble in an open fire; 50 parts of pure carbonate lose 22 of carbonic acid gas, and 28 of lime remain. In this condition it is termed QUICKLIME, or BURNED LIME.

299. Dip quicklime into water, remove it immediately and cover it. It soon swells, and falls to powder, combining with the water it had absorbed; the compound is termed SLACKED LIME, or HYDRATE OF LIME.

300. Put a table-spoonful of slacked lime into a beer bottle nearly full of water; shake the bottle, and allow the undissolved lime to subside; or filter, excluding the air, if a solution of lime be quickly required. It is termed LIME-WATER. Try it with vegetable blue and turmeric in solution; it affects them in the same manner as alkalis.

301. Expose lime-water in any vessel to the air. It soon attracts carbonic acid, and a crust of carbonate of lime appears upon the surface. Mortar used in building is composed of sand and lime mixed with water, and hardens as the lime attracts carbonic acid.

302. Put 1 or 2 ounces of lime-water into a glass jar, and add carbonic acid water (180); carbonate of lime falls; add more carbonic acid water and the carbonate is dissolved. Many natural waters contain lime dissolved by excess of carbonic acid; exposed to the air, the excess escapes, and carbonate of lime is deposited, encrusting with a stony matter any substance upon which it may fall.

303. Pour aqueous muriatic acid diluted with twice its bulk of water upon fragments of carbonate of lime, so long as any effervescence appears. The changes described in 177. take place. Any mineral which dissolves with effervescence in dilute muriatic acid, and which gives a mass that slacks like lime after heating to redness for some time, may be regarded as a limestone.

304. Take the solution of muriate of lime prepared as above (303); pour a portion into 5 or 6 wine glasses; leave one as it is, and add different quantities of water to the rest. On mixing aqueous sulphuric acid with each, different phenomena are presented. Where no water is added, the mixture becomes solid, sulphate of lime falls, composed of sulphuric acid and lime, muriatic acid gas escapes, which must be avoided. In the others, the muriatic acid is retained by the water, and the sulphate of lime is precipitated unless a large quantity of water be present to dissolve it.

305. Mix with water powdered sulphate of lime (which has been heated previously to expel water) so as to form a thick fluid like cream. Put it in this condition into any mould, or upon any coin, so as to take an impression; it gradually combines with the water, and forms a solid compound. The powder is usually termed Plaster of Paris, as the mineral from which it is made abounds at Paris. It is usually sold fit for mixing with water.

306. Add a solution of carbonate of soda to a solution of muriate of lime; carbonate of lime falls, the other substances remain in solution.

307. Add oxalate of ammonia to any solution of lime, neutralizing it at first with ammonia if it be acid; oxalate of lime, which is very insoluble, immediately appears.

308. MURIATE OF LIME in powder attracts moisture quickly from the air, and is much used in drying gases.

309. CHLORIDE OF LIME is formed by exposing slacked lime in powder to chlorine gas. Water dissolves it abundantly, and the solution is much used as it abounds in chlorine. The chlorine acts most effectually when acids are added to detach the lime.

CHAP. XIX.—BARYTA, STRONTIA AND MAGNESIA.

310. BARYTA is similar to lime, and is used principally as it detects sulphuric acid when added to any solution containing it.

311. STRONTIA also resembles lime. It is used in the prepa-

ration of deflagrating mixtures, where a bright crimson light is required. Mix muriate or nitrate of strontia with alcohol in an evaporating basin or metallic cup, inflaming it and heating the mixture. The alcohol burns with a crimson tint. A large sheet of paper dipped in the mixture and inflamed shews the tint very distinctly.

312. **MAGNESIA** is found in bittern, the liquid that remains after boiling down sea-water for the preparation of common salt; it is there combined principally with sulphuric and muriatic acids. It is also found in some varieties of limestone, and in many natural waters. Magnesia is mild compared with the preceding earths, and does not corrode animal substances, so that it is often given medicinally to neutralize acids. It is very sparingly soluble in water.

313. **SULPHATE OF MAGNESIA** or **EPSOM SALTS** contain sulphuric acid and magnesia; they are prepared by crystallization from bittern, or from natural waters in which it abounds. Fatal accidents occurring often in consequence of oxalic acid being mistaken for epsom salts (sulphate of magnesia), the following characters ought to be studied experimentally; the last two may be seen by putting the materials in small quantity upon a slip of glass, adding the tests in solution.

Tests.	Oxalic Acid.	Sulphate of Magnesia.
Taste,	Acid,	Bitter.
On red-hot cinders,	Dissipated,	White mass left.
Vegetable blue,	Reddened,	No effect.
Alkaline carbonates,	Effervescence,	White precipitate.

Symb. of Oxalic Acid. $\text{C}^2 = \text{O}^3 + \text{C}^2$, or $= \text{C} + \text{C} = 36$.

CHAP. XX.—ALUMINA. SILICA.

314. **ALUMINA** or oxide of aluminum abounds in clay, and is distinguished from preceding earths by its insolubility in water, and by being soluble in a solution of potassa. When uncombined it is insipid and inert.

315. **ALUM** is one of its principal compounds, and contains alumina, potassa, sulphuric acid, and much water of crystallization. Its solution reddens litmus, but scarcely affects cabbage.

316. Add a little ammonia, potassa or soda, to a solution of alum; it unites with part of the acid, and the alumina falls.

317. Heat alum in a red hot iron cup; it soon melts, water of crystallization is expelled, and a spongy mass is obtained, termed **BURNED ALUM**.

318. **COMMON CLAY** may be fused by a sharp heat, and becomes red before it melts, the iron it contains attracting oxygen.

319. Fire-clay is less fusible, and is used in preparing bricks, which may be exposed in furnaces to a strong heat. Fine varieties of clay are used in the manufacture of **CRUCIBLES**, **POTTERY-WARE**, and **PORCELAIN**.

320. **SILICA** consists of silicium 8 + oxygen 8; it is, like alumina, a very abundant earth, constituting the principal ingredient of flints, of the sand of the sea and of the desert, and of many rocks and minerals. Quartz is composed of silica nearly pure. Silica, in its ordinary form, is insoluble in water.

321. Mix intimately 200 grains of fine sand, and 600 of pure carbonate of potassa; fuse the mixture in a crucible capable of containing four times as much. Carbonic acid escapes, the silica and potassa combine and produce glass. Pour out the glass on an iron plate, and dissolve it in water, the large quantity of alkali rendering it soluble in this fluid.

322. Add to the solution muriate of ammonia, also in solution. The muriatic acid of the muriate unites with the potassa of the glass, and the silica falls.

323. With less alkali, glass is formed insoluble in water. **COMMON BOTTLE GLASS** is made of coarse sand, and any alkaline salt or earthy matter which can render it fluid when heated. **PLATE** and **WINDOW GLASS** are made with purer sand and alkali. **FLINT GLASS** is composed of similar materials, with the addition of oxide of lead, which gives more weight and lustre to the glass, and also allows it to be worked at a reduced temperature.

324. **COLOURED GLASSES** are formed by heating glass with various metallic oxides. Cobalt gives a fine blue; with manganese an amethystine tint is seen. Gold produces a ruby colour; copper and chrome give green.

325. All vessels of glass must be cooled very slowly after they are made, or annealed, as this is termed, otherwise they are very easily broken. When a piece of any fused rock or glass is cooled with extreme slowness from a high temperature till it becomes solid, it crystallizes, and presents the appearance of a stone. But if cooled quickly, a glassy substance is observed.

CHAP. XXI.—COMMON METALS.

IRON.

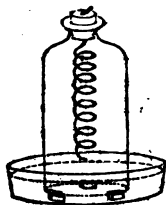
326. In ores of iron this metal is generally combined with oxygen and earthy substances. Charcoal, heated with the ore, removes oxygen, and lime is added to unite with the earthy matter, forming a fluid, in which the metal falls. When removed in this condition it is termed **CAST-IRON**. Purified afterwards by fusion, and by hammering it when stiff and agglutinated, it becomes **MALLEABLE-IRON**. **STEEL** is produced by heating it subsequently in charcoal, becoming extremely hard when suddenly cooled.

327. Put a tea-spoonful of iron-filings on a plate, moistening them from day to day till they become **RUST**, by attracting oxygen from the air.

328. Moisten a similar quantity in any flask or jar, and pour cautiously an equal bulk of aqueous nitric acid upon them. It is rapidly decomposed; nitrous acid escapes, and the iron is oxidated.

329. Prepare a coil of thin iron-wire, tie a thread at the extremity, dip it in melted sulphur, inflame it, and introduce it into a bottomless bottle of oxygen, after placing it in a basin with water, as in Fig. 68, with a plate of iron, or some sand, below. The iron oxidates, the oxide melting and falling through the water.

Fig. 68.



330. Mix, in a flask or jar, the materials employed in preparing hydrogen, using iron instead of zinc. (See 112, 113, and 120.) Filter the liquid procured, and, if no crystals appear, evaporate the solution and set it aside, that green crystals of **SULPHATE OF IRON** may be formed.

331. Fill a crucible half full of the crystals, and expose it to a dull red heat, **RED OXIDE** of iron, called also **PEROXIDE**, remains. the oxide in the sulphate attracting oxygen from part of the acid as it is expelled by the heat.

332. Compounds of the oxide with acids are usually green, but the red oxide, which is nearly the same as rust, produces reddish compounds. Mix an ounce, by measure, of aqueous muriatic acid with 6 ounces of water and a small table-spoonful of the red oxide in a flask, keep the mixture in a warm place for some hours,

shaking it occasionally, and filter it afterwards, to separate the solution from any excess of iron. The compound is termed **PERMURIATE OF IRON**.

333. Mix 500 grs. of flowers of sulphur with 1000 of bright iron-filings in a Florence flask, and heat it on a chauffer of red hot cinders. Heat and light are evolved as they combine, and sulphuret of iron is formed.

334. Dissolve 100 grs. sulphate of iron (**GREEN VITRIOL**) in 2 ounces of water, and pour a few drops into 6 glasses, jars, or flasks, previously filled nearly full with water.

- I. Into one pour potassa in solution; oxide of iron falls, combined with water. Expose it to the air, it slowly attracts oxygen, and becomes rust.
- II. To another, add carbonate of potassa; carbonate of iron falls.
- III. Add a little of the third to a large quantity of lime-water; oxide of iron is again precipitated.
- IV. Add feroprussiate of potassa in solution to the fourth. (See 4.)
- V. Add to the fifth a drop of hydrosulphuret of ammonia; sulphuret of iron is precipitated. $HS + NH^3 + S \cdot Fe = SFe + H + S + NH^3$.

In all these experiments, the sulphuric acid remains in solution with the alkali or earth in the precipitating solution employed.

VI. Add an infusion of galls to the sixth; gallate of iron, the colouring matter of ink, slowly appears.

335. Dilute a little ink with water, and add chlorine water or oxalic acid; the colour disappears.

Repeat all these experiments, using a solution of the permuriate of iron diluted in the same manner as the sulphate. Observe the difference of tint in most of the precipitates formed from this solution.

LEAD.

336. Heat lead to redness in a crucible or iron ladle; it soon oxidates if exposed to the air, and the oxide melts. **RED OXIDE**, or **YELLOW OXIDE** of lead, in powder, is obtained if it be cautiously heated without being fused. Observe the beautiful iridescence as, on removing the oxide from the surface, a fresh portion of metal is exposed to the air.

337. Dissolve 200 gra. of acetate of lead (sugar of lead) in 4½ ounces of water, filter it, and pour a part into 10 different glasses. To the first six add the reagents described in 76. Potassa and lime separate the oxide. Carbonate of potassa gives carbonate of lead. The hydrosulphuret of ammonia gives black sulphuret of lead, and is much employed in detecting this metal in solution. All the other substances produce white precipitates.

338. To the seventh glass add sulphuric acid or any sulphate in solution; white sulphate of lead falls. To the eighth add muriatic acid or any muriate; white chloride of lead appears. With the ninth mix a solution of iodide of potassium: yellow iodide of lead is precipitated.

339. In the tenth, put a small fragment of zinc; it takes away all the acetic acid and oxygen, and metallic lead is slowly deposited in crystals. This experiment may be varied by diluting the solution with an equal bulk of water, placing it in a narrow glass, and suspending the zinc at the top of the solution. The lead appears in an arborescent form, producing what is commonly termed the LEAD-TREE.

340. Acetic and nitric acids act most powerfully on lead, corroding it, and forming compounds soluble in water. Oxide of lead is used in glazing pottery ware, and is often dissolved by vinegar or other acescent substances, which then become poisonous. Sulphureted hydrogen gas alone, or in combination with ammonia, is used to detect lead (337). Waters abounding in carbonic acid corrode lead, and become unfit for daily use when kept in leaden cisterns.

COPPER.

341. Expose metallic copper to a dull red heat for half an hour, allowing the air to play freely upon it, and then plunge it suddenly under water; the oxide formed on the surface is speedily separated, and the metal presents its proper metallic lustre.

342. Put several slips of metallic copper into 2 drams of nitric acid, diluted with twice their bulk of water. The copper is quickly dissolved, part of the acid communicating oxygen, the rest combining with the oxydated metal.

343. Put a plate of iron into a solution of sulphate of copper (blue vitriol). The copper appears in the metallic form, the iron uniting with all the acid and oxygen previously combined with it.

If fragments of zinc, or a few iron nails, be boiled with any solution of copper in an acid, the whole of the copper is soon precipitated.

344. Add a little ammonia to a solution of copper; the oxide is immediately precipitated; on adding more, the liquid assumes a deep blue colour, and the oxide is dissolved. Copper and brass vessels (brass consists of copper and zinc) are frequently corroded when incautiously used in some culinary operations; as its solutions are poisonous, liquids suspected to contain it ought to be tested by adding ammonia to them, observing if a deep blue colour be produced, which indicates the presence of copper.

345. Arrange six glasses, each containing a solution of sulphate of copper, prepared in the same manner as the sulphate of iron solutions described in 334. Add to them the tests directed to be applied to the sulphate of iron; similar changes take place, but the tints are different.

ZINC.

346. Zinc is a brittle metal, having a white colour with a shade of blue.

347. Heat a few fragments of zinc to bright redness in an open fire, or in a crucible. The zinc is soon converted into vapour, and burns with a brilliant flame as it acts on the oxygen of the air.

348. Melt 600 grains of copper in a crucible, heating it to bright redness in a furnace, and covering it with a tea-spoonful of salt or charcoal to exclude the air. Add 200 grains of zinc previously well heated, that it may be freed from every trace of moisture, and mix them well by stirring with an iron rod. Brass is formed as the copper and zinc combine. Remove any oxide when it is cold by a file, and the yellow colour of the brass becomes apparent.

TIN.

349. Tin has a brilliant white appearance when pure, and is malleable and ductile. Heat tin in a crucible; it is soon covered with an infusible oxide.

350. Pour upon tin, in fragments, a little aqueous nitric acid, diluted with an equal bulk of water; the tin quickly attracts oxygen, and assumes the form of a white powder.

BISMUTH.

351. Bismuth is a brittle metal, having a white colour with a shade of red. Heated in a crucible it oxidates much in the same manner as lead. It is distinguished by its great fusibility, a property which many of its compounds also present.

352. Heat 800 grains of bismuth with 400 of tin and 400 of lead in a crucible till they melt. A compound is formed so fusible that it becomes liquid when heated to 204.

353. Melt half of the above in boiling water, and add 100 grains of mercury; the compound now becomes fluid at 170. Many toys are made of this composition, which melt when they are put into warm fluids.

ANTIMONY.

354. This is a very brittle metal, having a brilliant white colour and metallic lustre. Mix intimately in a crucible 400 grains of iron filings and 800 of sulphuret of antimony, heat the mixture to bright redness in a crucible, then add 100 grains of nitre in powder, when the crucible is cold; on breaking it with a hammer, the antimony will be seen below, and a compound of sulphur and iron above. The nitre promotes the separation of the antimony.

355. Mix 600 grains of nitre, 200 of sulphur, and 100 of sulphuret of antimony; place it upon an iron or earthen cup, and apply a lighted match. A brilliant deflagration takes place; the mixture is termed the BLUE SIGNAL-LIGHT. It can be seen at the distance of 50 miles.

CHROME, MANGANESE, ARSENIC, AND COBALT.

356. CHROME.—The most important compound of this metal is the bichromate of potassa, which is commonly prepared by heating the ore with nitre, when the chrome becomes chromic acid by attracting oxygen from the nitre; it combines at the same time with the potassa, part of which is afterwards withdrawn by another acid.

357. Heat a few grains of the bichromate to redness; part of the chromic acid loses oxygen, and becomes green oxide of chrome.

358. Prepare 4 glasses, each containing a little of the bichromate in solution.

I. Add to one carbonate of potassa in solution; it combines with the excess of acid, and yellow chromate of potassa is formed.

II. Proceed as in 14, page 3.

III. Add nitrate of mercury in solution to the third glass; chromate of mercury falls in the form of an orange-coloured powder.

IV. Mix a few drops of a solution of nitrate of silver with the bichromate in the next glass. Brick-red chromate of silver is seen.

359. Mix intimately 95 grains of the bichromate with 110 of common salt; heat the mixture in a retort with $2\frac{1}{2}$ drams by measure of aqueous sulphuric acid. Chlorine and chrome, or oxide of chrome, combine and produce a brilliant ruby-coloured vapour, CHLOROCHROMIC ACID, which may be condensed in a receiver; avoid the fumes as the process advances. Pour the product into three wine glasses, and add cautiously a drop of alcohol to one, of aqueous ammonia to the second, and a grain or two of sulphur to the third. In each case, heat and light appear, from the action of the chlorine on the hydrogen of the first two compounds, or on the sulphur, and green oxide of chrome is at the same time seen. These substances should be suspended at the extremity of a long cane before they are added to the fluid.

360. MANGANESE.—Heat 100 grains of the binocide (common peroxide) of manganese with 300 of nitre, in a crucible, to redness for half an hour. It attracts oxygen from the nitre, and unites with the potassa; water dissolves it, giving a fine green-coloured solution, which becomes purple and of a pinkish hue as it is merely exposed to the air, or diluted with an additional quantity of water. Hot water induces these changes much more speedily than cold water. See 103, 107.

361. ARSENIC.—The violent poison known by this name consists of oxygen and the metal arsenic: it may be distinguished by the following characters. Heat a grain in a dry test tube; it is volatilized, and condenses on the sides of the tube in crystals, which have a brilliant lustre.

362. Heat a grain in another tube, after mixing it with twice its bulk of charcoal. Metallic arsenic condenses on the side of the tube, presenting a steel-grey lustre.

363. Mix a little with a drop of a solution of nitrate of silver, and add a minute quantity of potassa, yellow-coloured arsenite of silver is seen. Treat another portion in the same way with sulphate of copper; a similar action takes place, and grass-green ar-

senite of copper appears. Add a little boiling water in both cases if the proper tint is not seen at first.

364. COBALT.—Write on paper with a dilute solution of muriate of cobalt; nothing is observed when it is dry; heat it, and the characters traced with it appear of a fine blue colour. If the solution be mixed previously with common salt, a green tint appears. The colour fades again on cooling.

MERCURY, SILVER, GOLD, AND PLATINUM.

365. Mercury or quicksilver. Boil 10 or 12 grains of mercury in a test-tube, holding it in the flame of a spirit-lamp. It rises in vapour, and condenses in brilliant globules in the upper part of the tube.

366. Heat 20 grains of mercury in a small evaporating basin, with 1 dram by measure of nitric acid; much gas is evolved; the mercury takes oxygen from part of the acid, and combines with the rest. Heat the liquid till a dry mass appears, and then increase it gently till it becomes of a very deep red. Binoxide of mercury is thus obtained, which brightens as it cools, and presents small crystals. Heat a few grains in a test tube, placing it in a spirit lamp; oxygen is expelled, and the mercury volatilized, condensing ultimately, as in 365.

367. Mix 20 grains of mercury with 1-3d of the acid directed above, dilute it with three times of bulk of water, and allow the action to go on with little heat. A nitrate is formed, in which the mercury has little oxygen combined with it.

368. Heat in a test-tube, as in 365, 20 grains of mercury and 3 grains and 1-5th of sulphur. They combine, and produce VERMILLION, or BISULPHURET OF MERCURY, which assumes its usual tint when reduced to powder; it is obtained with a brilliant hue only by slowly or repeatedly subliming it.

369. Heat 20 grains of mercury and 25 of iodine in the same manner; a brilliant yellow biniodide is produced, which soon assumes a scarlet hue.

370. Dissolve a few grains of BICHLORIDE OF MERCURY, a virulent poison, in an ounce of water, and divide it into 4 portions. Potassa and lime-water separate binoxide, the mercury deriving oxygen from the water. Iodide of potassium produces biniodide of mercury. Hydrosulphuret of ammonia gives bisulphuret of mercury, dark in colour till it is sublimed.

Animal and vegetable matters subject to decay in damp situa-

tions, as wood and canvas, are often steeped in a solution of the bichloride to preserve them.

371. Put a piece of tin-foil, 2 inches long by 1 broad, upon a sheet of paper; drop a little mercury upon it, spreading it upon the tin with a hare's foot. Cover it with a slip of paper twice its own length, and place over the paper any plain piece of glass. On drawing out the paper, pressing down the glass all the time, the tin and mercury adhere to the glass, so as to produce a small looking-glass.

372. SILVER.—This metal is distinguished by its pure white colour and brilliant lustre. It is very malleable and ductile.

373. Add silver in fragments, so long as it is dissolved, to aqueous nitric acid, exposed to heat, and diluted with three times its bulk of water. Part of the acid is decomposed, oxidating the metal, and the remaining portion combines with the oxide, forming nitrate of silver. Crystals are deposited as the solution cools; when these are fused to expel any adhering water or excess of acid, common LUNAR CAUSTIC is procured.

374. Fuse half a grain of nitrate of silver on a slip of glass, heating it by the flame of a lamp. All the nitric acid and oxygen are expelled; metallic silver alone remains.

375. Dissolve 20 grains of nitrate of silver in an ounce of water, to be used as a solution for experiments with silver. Arrange 6 glasses with water, adding to each a few drops of the solution of silver, and afterwards the following tests in solution.

376. Potassa separates oxide of silver as an ash-grey powder.

377. Carbonate of potassa precipitates carbonate of silver.

378. Lime precipitates oxide of silver.

379. Muriatic acid, chlorine, and common salt, precipitate chloride of silver.

380. Chloride of silver is white and curdy, but assumes a dark colour on exposure to the light.

381. Put a fragment of copper into one glass, of zinc into another, and a few grains of mercury into a third; on covering each with a little of the solution of nitrate of silver, metallic silver soon appears, a corresponding quantity of the other metal which precipitates it being dissolved.

382. Write on a piece of linen with a pen dipped in the solution of the nitrate, and, when dry, immediately spread upon it a solution of potassa or soda. The oxide of silver is left insoluble upon the cloth, and soon darkens in its tint, leaving a permanent mark

upon the cloth. A solution of the nitrate forms common marking ink. The alkali is used to remove the nitric acid, and prevent the cloth from being corroded. A carbonated alkali, as common soda, is often used instead of the purer alkali; 100 grains may be dissolved for this purpose in an ounce of water.

383. GOLD.—This metal is distinguished by its malleability and fine yellow colour; it is found principally in a pure form. Gold-leaf is so thin that 282,000 are required to make up the thickness of an inch. In gilded silver-wire, the gold is less than the 3,900,000th part of an inch in thickness. It is not affected by air or oxygen at any temperature, and common acids have no action upon it.

384. Put four or five gold leaves into an evaporating basin; pour upon them a few drops of nitric and of muriatic acids. Chlorine from the muriatic acid quickly dissolves the gold. Evaporate the solution to dryness, so as to expel excess of acid; terchloride of gold remains.

385. Dissolve the terchloride in 30 or 40 drops of water. Dip a slip of glass into the solution, and heat it over a lamp; the chlorine is expelled, and metallic gold remains. On looking through the glass, a purple tint is often seen. Write upon the palm of the hand with a pen dipped in a solution of the terchloride; it acquires a purplish tint, which disappears in a few days.

386. Heat a slip of glass in the flame of a lamp, touch powdered borax with it, when it immediately adheres. A drop of the solution is then to be put upon the borax, when it is to be heated by a lamp, taking care not to smoke it. A beautiful ruby-coloured compound appears; metallic gold is afterwards observed if the heat be continued long.

387. Put three drops of the solution upon paper, and add the following tests in solution.

Sulphate of iron, which precipitates metallic gold of a dark colour, being in a minute state of division.

388. Muriate of tin produces a purple precipitate, containing gold and oxide of tin, and usually termed the Purple Precipitate of Cassius.

389. Hydrosulphuret of ammonia produces a dark coloured sulphuret of gold.

390. PLATINUM is a metal much prized in making crucibles, capsules, and numerous other articles of chemical apparatus, as it is scarcely affected by any ordinary chemical agent, many of which

corrode other metals. It is also very infusible, not being melted by the heat of any common furnace.

391. Dissolve 5 or 6 grains of platinum wire in a dram of nitric acid, mixed with an equal bulk of muriatic acid. Add more acid if it be required, and evaporate cautiously to dryness. Bichloride of platinum is obtained: dissolve it in 1 or 2 drams of water. Add a solution of iodide of potassium to a part of it; a deep coloured compound immediately appears.

392. Add a solution of muriate of ammonia to another portion; a compound of this substance and the platinum is soon precipitated of a yellow colour. Heated to redness in a crucible, every thing is expelled except the metallic platinum; it is not fused, but remains in minute particles, in which condition it absorbs much oxygen from the air, and when hydrogen is directed upon it a red light is observed, and the hydrogen is soon inflamed.

CHAP. XXII.—ORGANIC CHEMISTRY.

393. ORGANIC CHEMISTRY signifies the chemical history of the various proximate principles which have been observed in the animal and vegetable kingdoms, and which are there associated together so as to produce a peculiar structure, termed Organic, such as is never seen in any of the products of the mineral kingdom. Gum, sugar, starch, woody fibre, albumen, fibrine, gelatine, and all those numerous substances of which plants and the bodies of animals are composed, constitute those proximate principles which are the products of animated nature. All of them, however, are composed principally of a very few of the same elements.

394. Vegetable substances are composed principally of carbon, oxygen, and hydrogen; nitrogen is more rarely observed in them. Animal matters consist generally of carbon, oxygen, hydrogen, and nitrogen; the presence of nitrogen gives to them many of their more peculiar properties by which they are distinguished from vegetable substances.

395. All animal and vegetable substances are decomposed by heating them in an open fire, burning as their carbon and hydrogen act freely on the oxygen of the air. They leave in general a small quantity of ash, composed either of potassa, various salts containing soda, potassa, or lime, and traces of iron or other metals.

396. When heated in vessels so that the air is excluded from

them, much carbureted hydrogen gas is evolved; water, tar, and numerous oily or resinous compounds, may also be separated by distillation, and a considerable quantity of charcoal remains.

CHAP. XXIII.—VEGETABLE CHEMISTRY.

397. Seeds consist of the GERM, which produces the future plant. GERMINATION is the process by which the germ begins to grow from the seed, one part, the RADICLE, descending into the earth and forming the roots, while another, the PLUMULA, ascends and produces the stem. When the seed is planted, sugar is formed by the matter around the germ, constituting the first nourishment it receives.

398. VEGETATION includes all those processes which are necessary to the growth of the plant after germination. By ABSORPTION, nutritious matters are taken up by the roots and other parts of plants; by CIRCULATION the sap is carried to the leaves, where a process similar in some respects to the RESPIRATION of animals is carried on, after which it is conveyed where the different proximate principles are separated from it by the process of SECRETION.

CHAP. XXIV.—VEGETABLE ACIDS.

399. OXALIC ACID is very soluble in water, crystallizes with facility when its watery solution is concentrated. It is very acid, and a virulent poison. Employed in testing lime, in polishing brass, and in cleaning leather. See 313.

400. ACETIC ACID consists of $4C + 3 \cdot H = 51$. It is the acid of vinegar, and is formed also in large quantity by heating wood, excluding the air; obtained from this source, it is often termed pyroligneous acid. In a concentrated form it has a very pungent and fragrant odour, and is then used for vinegarettes.

401. Take 1 ounce of vinegar by measure, mix it with a little vegetable blue, which is reddened, and add to the solution bicarbonate of potassa in fine powder till the acetic acid is neutralized, the blue tint being restored. Note the quantity of bicarbonate employed, and calculate the quantity of acetic acid in the solution, 101 grains of the bicarbonate containing a sufficient quantity of potassa to neutralise 51 of real acetic acid.

402. Acetic acid corrodes many metals; with oxide of lead it

forms the acetate or sugar of lead. With oxide of copper verdigris is produced.

403. **TARTARIC ACID** is procured from cream of tartar. It is not volatile like the acetic acid, and is decomposed when heated. It consists of oxygen 40 + carbon 24 + hydrogen 2 = 66. One equivalent of water is always combined with it, in the condition in which it is obtained; 75 grains of the crystals are accordingly always used where 66 of the acid are required.

404. Dissolve 75 grains of crystallized tartaric acid in a tumbler 1-3d full of water, and dissolve 101 grains of bicarbonate of potassa in another, adding a little sugar and ginger or cinnamon powder to the mixture, if required to communicate any flavour to it; on mixing the solutions, an effervescing draught is formed, from which the carbonic acid escapes quickly; tartrate of potassa being formed in solution, and carbonic acid gas rapidly disengaged. For an ordinary draught, half the above quantity of materials are generally employed, a few grains of acid being added in excess, to communicate an acidulous taste.

405. Add a few drops of a solution of tartaric acid to a concentrated solution of carbonate of potassa, till a neutral tartrate of potassa is formed; it is very soluble in water. Add afterwards more tartaric acid till the solution is very acid; cream of tartar (bitartrate of potassa) falls down in small crystalline grains.

406. **CITRIC ACID** is obtained from the juice of the lime and of the lemon. It is soluble in water, crystallizable, easily decomposed by heat, and, when crystallized, may be kept for any length of time, not being apt to decompose like the juice from which it is separated.

407. Put 20 or 30 grains of **BENZOIC ACID** into a Florence flask, and expose it very slowly and cautiously to the heat of a lamp; it is soon melted, and converted into vapour, condensing in beautiful crystals upon the upper part of the flask, if the heat be not too great. If a piece of thread or any solid substance be suspended in the interior of the flask, the crystals collect very beautifully upon it.

408. **PRUSSIC or HYDROCYANIC ACID** exists in minute quantity in a number of flowers and fruits, communicating to them a very rich and agreeable flavour, as in the flower of the hawthorn; in the peach, and in the almond. It contains no oxygen, and is composed entirely of cyanogen and hydrogen; 26 parts of cyanogen contain 12 of carbon and 14 of nitrogen. Symb. C^2N . With

1 of hydrogen, 26 of cyanogen produce 27 of prussic acid. Symb. HC^2N . It is distinguished by its great power, when in a concentrated form, in affecting the animal economy, a few drops being quite sufficient, when laid upon the tongue of a large dog, to produce instant death, almost with the rapidity of lightning. Laurel water, noyau, and many other liquids, contain a portion, and sometimes give rise to fatal effects, when the prussic acid is present in too large quantity. No fact appears more singular at first, than that a principle of such powerful activity in reference to the animal economy, should consist of the very same elements as are consumed every day in our food; but chemistry abounds in facts such as these, as is observed, for instance, in the compounds of oxygen and nitrogen, these elements constituting in one proportion the air that we breathe, and in another the corrosive nitric acid or aquafortis.

409. Prussic acid is usually prepared from ferroproussiate of potassa, a yellow coloured salt, which is formed on the large scale by heating animal matter with potashes and iron. This salt is mixed with half its weight of sulphuric acid, previously diluted with three or four times its bulk of water, and allowed to cool before it is poured upon the salt in powder; the acid unites with the potassa, and the prussic acid, which is united with iron in the salt, may be condensed in a receiver in combination with the water which distils along with it. The acid should be prepared only in small quantity, and always diluted with water, by those not accustomed to operate with it, so as to prevent any risk of accident. The receiver ought to be kept very cold. Five or six grains of the salt are quite sufficient to give enough of the diluted acid, to allow its flavour, so similar to that of the peach, to be recognised.

410. A number of compounds, called **VEGETABLE ALKALIS**, have been discovered in many of the more important medicinal substances obtained from the vegetable kingdom; in these the medicinal properties of the substances from which they are extracted are found more particularly to reside. **MORPHIA** is the name of the vegetable alkali procured from opium. **QUINA** and **CINCHONIA** are procured from Peruvian bark.

CHAP. XXV.—OILY AND RESINOUS SUBSTANCES.

411. All oily and resinous substances are composed, in general, of about 80 per cent. of carbon, 11 or 12 of hydrogen, and 9 or 8

of oxygen; some contain no oxygen. Exposed to the air, on any extensive surface, they are apt to imbibe oxygen slowly, even at natural temperatures, gradually becoming warm, and bursting ultimately into flame, sometimes in a few days, but often not till weeks or months have elapsed. Numerous fires have been traced to the spontaneous inflammation of oil spread upon tow or cotton.

412. Volatile oils rise in vapour at the temperature of boiling water, if mixed with this fluid; they burn in general with much smoke, and are easily inflamed; some carbon is deposited.

Put an ounce of cinnamon bark in fragments into a retort, cover it with water, and distil a portion of the water into a receiver; a portion of volatile oil, having the odour of the cinnamon bark, rises along with it, and renders it milky as it condenses in the receiver.

413. Pour a few drops of oil of turpentine upon a piece of paper, and heat it gently before the fire, or over a lamp, at a distance from the flame. It is soon entirely dissipated, leaving no greasy stain upon the paper.

414. Dip a piece of paper in oil of turpentine, put upon it a grain of chlorate of potassa in powder, and touch it with a drop of aqueous sulphuric acid; peroxide of chlorine (see 244) is immediately liberated, and inflames the turpentine.

415. Put two drams, by measure, of oil of turpentine into any cup or basin placed in the open air, or at a large ventilator. Put into a glass, tied to the end of a long stick, four drams by measure of strong aqueous nitric acid, and one of aqueous sulphuric acid, taking care that there is no turpentine in the measure employed. Hold the mixture as far away from the face as can be done conveniently, and pour it upon the oil of turpentine; much oxygen is immediately communicated to it, and the turpentine is quickly inflamed.

416. **FIXED OILS** are frequently obtained by expression; they are thicker than volatile oils, unctuous to the touch, and require a temperature about 600 to convert them into vapour. They may be regarded generally as compounds of two principles, **ELAIN**, or the more fluid portion, and **STEARIN**, the more solid part, which freezes in cold weather before the elain. When the oil is boiled with potassa or soda in solution, soap is formed, and a substance having a sweet taste is separated.

417. Heat a few drops of any fixed oil upon paper; it is not volatilized except by a heat sufficient to decompose the paper.

418. Boil soft soap in twice its bulk of spirit of wine, filtering the solution if it be not transparent.

419. Add a portion to common water; if very pure, only a slight opalescence is observed.

420. Add a little muriate or sulphate of lime to water, in another glass, and mix with it a portion of the solution of soap; the acid unites with the alkali of the soap, and remains in solution, a compound of the earth and oily matter of the soap separating in the form of a curdy precipitate.

421. To another solution of the muriate or sulphate of lime, as in 420, add carbonate of potassa, or of soda, so long as any precipitate is formed. The acid of the earthy salt unites with the alkali of the carbonate, and the lime and carbonic acid fall down as an insoluble carbonate. Add the solution of soap to the liquid in this condition; it is not decomposed; the acid of the earthy salt is already combined with alkali, and the earthy matter has been precipitated so as to be incapable of affecting the oily or fatty matter.

422. Dissolve 10 or 20 grains of RESIN in three or four times its bulk of alcohol. Pour the solution into a large quantity of water; the alcohol unites with the water, and the resin is separated.

423. Perform a similar experiment, using CAMPHOR instead of resin; it is dissolved and precipitated in the same manner as the resin.

424. Heat a few grains of camphor in a tube by a small lamp. It soon melts, produces a transparent fluid, which is quickly volatilized, and condenses in a solid form in the upper part of the tube.

425. Put an ounce of WAX into a tea-cup or evaporating basin; melt it by placing it in boiling water, preventing any from mixing with the wax. Untwist a piece of cord, and dip the separate parts into the wax; cut them into lengths of 6 or 8 inches, to be used as matches in applying a light in chemical experiments.

CHAP. XXVI.—LIGNIN, GUM, STARCH, AND GLUTEN.

426. LIGNIN is the term applied to the woody fibre. Mix a few chips of wood with aqueous sulphuric acid. It is blackened, charcoal being separated as it is decomposed by the sulphuric acid. See 268.

427. Dissolve GUM-ARABIC in water, after reducing it to powder, placing it in a flask or cup heated by immersing it in boiling water. Mix a portion of the solution with an equal bulk of alcohol; the water unites with the alcohol, and the gum is separated.

428. Grate down several potatoes in a basin, covering them with water, and stirring the mixture for a little time; the STARCH which they contain separates from the fibrous matter, and may be seen at the bottom of the mass, being heavier than water, and insoluble in it when cold. See 254.

429. Mix starch with cold water, and then pour boiling water upon it; a strong gelatinous mass is formed, if too much water be not poured upon it. It is very nutritious. SAGO, TAPIOCA, ARROW ROOT, POTATO FLOUR, are all composed of starch.

430. Mix a table spoonful of wheaten flour with water, so as to produce a stiff dough. Spread it upon the palm of the left hand, hold it over a basin of cold water, and with the right hand pour water upon it so long as a milky fluid appears exuding from it, pressing it gently from time to time with the finger. Flour consists principally of starch and gluten mixed with gum and sugar. The water dissolves the gum and sugar; the starch is carried away mechanically suspended by the water, and GLUTEN remains on the hand. If the flour be of good quality, about one-third of its weight of gluten is usually obtained. Flour is often sold of such indifferent quality that little gluten is procured from it. Gluten is the most nutritious part of flour, and forms the numerous little cells that appear in fermented bread, as gas and vapour rise in the substance of the dough. It contains nitrogen along with carbon, oxygen, and hydrogen, resembling animal matter in its composition.

CHAP. XXVII.—SUGAR—VINOUS FERMENTATION—ALCOHOL.

431. Sugar consists of oxygen 8 + carbon 6 + hydrogen 1.—Symb. $\text{OCH} = 15$. Soluble in water and alcohol; decomposed rapidly, when heated in the open air, burning with flame. Found in the sap of vegetables, and extracted by evaporation and crystallization. MOLASSES or TREACLE and HONEY contain sugar

associated with different substances, which prevent it from crystallizing with facility.

432. When vegetable or animal substances are decomposed by the reaction of their elements, **FERMENTATION** is said to take place; and when sugar is decomposed in this manner, alcohol and carbonic acid being formed, it is termed the **VINOUS FERMENTATION**; 45 of sugar produce 22 of carbonic acid gas and 23 of alcohol. Symb. $3\text{OCH} = : \text{C} \& \text{OC}^2\text{H}^2$.

433. Dissolve 4 ounces of sugar in 10 of water; keep it at a temperature between 60 and 70 for some days, adding a little **YEAST**, the viscid matter that is formed during vinous fermentation, and which speedily causes the decomposition of the sugar to commence. In a few days a pungent fluid is obtained, having all the properties of **BEER**. If the liquid be bottled before the fermentation shall have been completed, the carbonic acid, formed afterwards, escapes with effervescence when the cork is withdrawn.

434. When grain is moistened, so as to enable germination to commence, much sugar is formed, as described in 397. The germination is then arrested to prevent the decomposition of the sugar, and **MALT** is thus produced. With the fermented infusion of malt, **ALE**, **PORTER**, and **SMALL BEER** are produced. The juice of the grape gives **WINE**; and **CIDER** and **PERRY** are obtained by fermenting the juice of the apple and the pear.

435. Fill a retort 1-3d full of Port wine, and distil one-half; **PALE BRANDY** is obtained. Distil ale in the same manner, condensing only 1-8th of the liquid used, **WHISKY** is obtained. In both cases, much water, and any solid previously in solution, as gum, sugar, colouring or astringent matter, remain in the retort; alcohol combined with water condenses in the receiver.

436. Distil whisky or brandy, till a half of the portion employed shall have condensed in the receiver; stronger alcohol is procured, more of the water remaining in the receiver. If the distillation be again repeated, mixing salt in fine powder with the liquid in the retort, very little water comes over with the alcohol.

437. Mix half an ounce by measure of aqueous sulphuric acid with 9 drams by measure of alcohol, and distil till a portion of liquid is condensed, equal in bulk to 1-3d of the alcohol used. The sulphuric acid retains part of the oxygen and hydrogen of the alcohol, and the liquid in the receiver is a very volatile fluid, usually termed **SULPHURIC ETHER**, as it is prepared by the action of

sulphuric acid. It is combined with a little alcohol, as formed at first. Symbol OC^4H^5 .

438. Take a tea-spoonful of each of the products of distillation referred to in the preceding paragraphs, and throw them upon red hot cinders. Observe how different the flame appears in each, being more luminous the stronger the spirit is; the ether burns with a much richer flame than the alcohol.

439. Alcohol boils at 176, and ether at 98, when they are extremely pure. Alcohol is much used for lamps, as it burns with a clear and smokeless flame, producing much heat.

CHAP. XXVIII.—COLOURING MATTER.

440. Cut a common red cabbage into small pieces, and boil it for a short time with no more water than is required to cover it. Use the solution procured in this manner, or by simply infusing the cut cabbage in boiling water, as the **CABBAGE OR VEGETABLE BLUE** so often referred to in the preceding pages.

441. Dip into the solution a number of slips of paper, 4 or 6 inches square; keep them there till they imbibe some colouring matter, and then dry them, excluding them afterwards from the action of the light, until they are required for use. Cut small slips, which may be touched with a minute quantity of the solution, to be tested to indicate the presence of acid or alkali, being reddened by one, and turned to a green by the other.

442. Dilute a solution of the vegetable blue, and try the action alternately of acids and alkalis upon it.

443. Boil litmus in 5 or 6 times its bulk of water; prepare test papers with the solution as in 443. They are reddened by acids, but not turned to a green by alkalis.

444. Pour upon a table-spoonful of turmeric placed upon a common plate 3 or 4 times its bulk of boiling water, and prepare turmeric test papers as in 443. They are of a fine yellow, and become reddish-brown by alkalis, but are not affected by acids.

445. Add a little alum in solution to a dilute solution of litmus in a jar or flask; mix a little potassa with the liquid till the alumina appears, which will combine with the colouring matter as it is precipitated.

446. Dip a piece of cotton cloth into a diluted solution of sulphate of iron, and allow it to dry; immerse it afterwards in an infusion of galls, containing gallic acid; it unites with the iron, and the cloth is died of a bluish-black colour.

447. Mix a little of the solution of the sulphate of iron with paste, spread it very thin upon cloth, and take up a little by pressing upon it any stamp or block of wood with a pattern cut upon it, which may be applied many successive times to different parts of the cloth if required; any plain piece of wood will do, if no pattern can be made. Dry it, immerse it in a little aqueous ammonia diluted with much water; the acid is removed, and the pattern appears on the cloth in the form of oxide of iron. Run a little water upon it, and pour upon one portion the infusion of galls. A black pattern is now seen upon a white ground. Put another portion into a basin of water, to which a few drops of ferro-prussiate of potassa in solution and aqueous nitric acid shall have been added. A blue pattern is now observed.

448. Put a number of flowers of any colour, and also several green leaves, into a vase of chlorine; all of them are quickly bleached.

449. Put a hank of unbleached yarn, and a number of strips of different coloured cloths, dyed with animal or vegetable colouring matter, into a solution of chlorine in water. They are all soon bleached by the powerful action of the chlorine. Similar experiments may be tried by adding a solution of chlorine to solutions of colouring matter in water. Chloride of lime dissolved in water may be substituted for chlorine, adding a few drops of acid.

450. Put several flowers into a large glass-jar, and inflame a little sulphur in a small metallic cup placed within the jar, as in Fig. 24. The sulphurous acid produced by the combustion of the sulphur bleaches a number of flowers. The purple grape hyacinth, the blue crocus, the violet, and many other blue flowers, do well for this experiment; the first is the best.

451. Hold some of the bleached flowers in vapours of muriatic acid gas, produced by pouring aqueous sulphuric acid on common salt; the acid acting on the base of the colouring matter produces a red tint.

452. Put another portion of the bleached flowers into a jar containing a very little strong aqueous ammonia; the vapour escaping from it turns them to a fine green.

CHAP. XXIX. ANIMAL SUBSTANCES. RESPIRATION.

453. Albumen, fibrine, gelatine, and oily or fatty matters, constitute the more abundant proximate animal principles.

454. **BONES.**—Heat fragments of bone in an open fire; all the animal matter is consumed, and the earthy matter, composed principally of phosphate with a little carbonate of lime, is left.

455. Heat another portion to redness in a covered crucible, so as to exclude the air; much charcoal is left with the earthy matter, producing ivory black.

456. **ALBUMEN.**—Put a portion of the white of the egg, which is composed principally of water with albumen, into six different glasses. Coagulate the albumen in all by adding successively aqueous sulphuric, nitric or muriatic acids, alcohol, infusion of galls, and bichloride of mercury. The coagulation of albumen by heat is familiar to every one. Mixed with cold liquids, which are afterwards heated, it coagulates and entangles all impurities, and is accordingly much used in clarifying fluids.

457. **GELATINE** constitutes **GLUE**, **ISINGLASS**, and the animal matter of jellies. Distinguished by its solubility in hot or cold water, and the tremulous jelly it affords on cooling.

458. Add an infusion of galls to a solution of gelatine; a copious precipitate appears similar in composition to those kinds of leather which are prepared by putting the skins of animals which are composed principally of gelatine into infusions of oak bark, these containing the vegetable matter called tannin, as well as the infusion of galls. The compound is termed **Tanno-Gelatine**.

459. **Fibrine** constitutes the solid part of muscular fibre.

RESPIRATION.

460. Respiration consists in the inspiration and expiration of air, which acts upon the dark coloured blood in the lungs, gives it a brilliant florid red colour, and renews it continually in its qualities so as to adapt it to the various purposes for which it is required in the living body. If we suppose 16 or 17 respirations to take place every minute, we may be allowed to estimate that man respires on an average 1000 times an hour, or draws upon the atmosphere, that great magazine of oxygen, no less than 24,000 times every day and night for nourishment and support, without which his existence could not be prolonged even for a few minutes. The great changes effected in the air are the removal of a part of its oxygen, which is replaced by carbonic acid gas, being thus vitiated in such a manner, and rendered so unfit for respiration, as to prove fatal to any one who might continue to respire for a long time the same portion of air.

461. Blow through a glass-tube into water tinged with litmus. The carbonic acid reddens the litmus.

462. Blow in the same manner into lime-water; carbonate of lime is quickly deposited.

463. Blow into a small flask with a tube, expelling as much air as possible from the lungs, and immediately introduce a lighted suspended candle; it is extinguished.

464. If we assume as an average that between 5 and 6 ounces of carbon are consumed daily in the production of carbonic acid, then 3 individuals will evolve carbonic acid containing 1 pound of carbon; and the following rough estimate will give some idea of the large quantity of carbon consumed by man alone; approximate numbers have been taken in estimating the population of different places to avoid fractions.

	Population.	Tons of Carbon consumed daily.	Tons of Carbonic Acid produced daily.
Edinburgh, .	150,000	22	80
London .	1,500,000	220	800
Whole globe.	800,000,000	117,333	426,666

The annual consumption of carbon, accordingly, by man alone, may be estimated at 42,826,666 tons, and the annual production of carbonic acid at 155,733,333 tons.

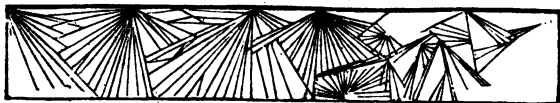
465. During the respiration of vegetables, at least in the sunshine, carbonic acid is decomposed, carbon retained, and oxygen evolved; in this manner, the two great systems of animated nature, each counteracting the influence of the other by those processes which are essential for their nourishment and support, are believed to maintain the air in that state of equilibrium which is so necessary for the existence of both.

CHAP. XXX.—FLAT GLASS, TUBE, AND BLOWPIPE APPARATUS.

466. When slips of glaziers' window-glass are properly selected, they may be used for the following purposes.

467. I. SOLUTION. Broad slips of the size seen in Figs. 69. and 70, or twice the length and breadth seen there, are best adapted for

Fig. 69.



this purpose ; they are held by one extremity, and a minute quan-

Fig. 70.



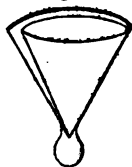
ty of the substance to be dissolved, about the size of a mustard seed, is placed at the other, covering it with 8 or 10 drops of the liquid used for solution.

468. II. BOILING LIQUIDS. Slips of the same size as Fig. 69. may be employed, but they ought to be selected as thin as possible; those which are about the 20th of an inch in thickness do well. The part heated should be covered for the length of an inch or two with the liquid to be evaporated; the slip may be placed before the fire, in a current of warm air, or one or two inches above the flame of a very small lamp or candle.

469. III. CRYSTALLIZATION. Solutions to be crystallized may be spread over the greater part of the glass, and left to evaporate spontaneously, or concentrated by heating, removing the slip from the heat the moment any solid appears on the edges; if the heat be continued longer, a confused mass is generally observed instead of crystals; Fig. 69. represents the appearance frequently seen where small needle-like crystals are produced. Glauber salts (sulphate of soda), oxalic acid, muriate of strontia, and bichloride of mercury, give solutions which crystallize with great facility.

470. IV. FILTRATION. When a solution is turbid, from the admixture of solid matter, it should be collected at one extremity; a small tapered piece of bibulous or filtering paper is then placed next it, as in Fig. 70, when the fluid in general passes along, and a drop of clear fluid is obtained at the pointed extremity of the paper. The glass slip should be gently inclined, and more water or other solvent should be added, if there be not enough to moisten the paper. When the solution does not filter readily in this manner, a square piece of paper may be folded in two, this being again repeated, so that on opening it in the manner seen in Fig. 71, the fluid may be poured into it as it rests on the side of the flat glass.

Fig. 71.



These slips, or the narrow slip, may also be used for PRECIPITATION. See V.

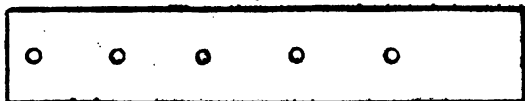
471. V. SLIPS FOR TESTING, STIRRING, and LIFTING Fluids. These are made of the form and size shown in Fig. 72. Dipped

Fig. 72.



into any solution, a portion adheres to the extremity; it may then be divided into many small portions, upon a broad slip of glass or paper, by touching it with the end of the slip to which the fluid adheres. The narrow slips being cleaned in a basin of water, may then be dipped into any tests, and applied to each separate portion distributed over the glass or paper as in Fig. 73.

Fig. 73.



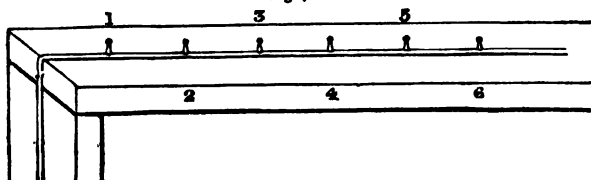
472. VI. For FUSION and DECOMPOSITION, the broad slips may be employed where an intense heat is not required. In examining the effect of heat where a more elevated temperature is necessary, the narrow slip should be employed, and no more taken up than can be lifted by the point, the quantity not exceeding in bulk the head of a small pin. Practise experiments of this kind with acetate of lead, red lead, sulphate of copper, sulphate of iron, nitrate of silver, terchloride of gold, and any other substances, the effect of heat upon which has already been described.

473. In experimenting with borax and metallic oxides or other substances, heat the pointed extremity for half a minute, dip it instantly into powdered borax, a portion of which immediately adheres; it is then brought in contact with the substance to be fused along with it, moistening it, if this be necessary, to make a little adhere. The material is usually heated in the flame of a lamp or candle; in the outer flame, *a a*, Fig. 30, hot air acts upon it, but in the inner flame, it is subjected to the action of hot carbon and hydrogen. Between these is the point of greatest heat.

474. Fig. 74. shews the arrangement adopted in placing the gas or other lamps, at Heriot's Hospital, in the Scottish Institution, in the School of Arts, and other places, where from 40 to 120 pupils operated at once. The benches are arranged so that the

teacher is in the centre, and able to command a view of them all.

Fig. 74.



Cups, glasses, or saucers, with the materials, are placed at one end of each, and a basin of water at the other.

BLOWPIPE.

475. Fig. 75. represents a blowpipe made of tin, with a brass nozzle inserted at the lower extremity. The upper part of the tube, into which air is blown by the mouth, is 3-10ths of an inch in diameter, the lower part an inch, and the nozzle, which proceeds from it, and is inserted into the flame of a candle, or of an oil, tallow, or gas lamp, terminates in an opening about 1-40th of an inch in diameter. By blowing through this tube, when the nozzle is held in any flame, it may be made to produce a conical flame, or BLOWPIPE DART, as it is frequently termed, with which numerous experiments may be performed, where small portions of matter are subjected to its influence. The outer part of the flame abounds in oxygen derived from the air, and is termed the OXIDATING FLAME; the inner part, when yellow, and loaded with hydrogen and carbon, is termed the DEOXIDATING FLAME. The carbon and hydrogen tend to remove oxygen. The blowpipe may be made 10 inches long.

Fig. 75.



476. By blowing with the cheeks distended like a trumpeter's, and endeavouring to renew the blast as speedily as possible when it intermits during inspiration, the habit of keeping up a continued blast is acquired, the air with which the cavity of the mouth is filled being used to maintain the stream, while a fresh portion passes down by the nostrils to the lungs.

477. When a metal is to be procured from an oxide, or any de-

oxidating effect to be produced, a charcoal support is used; a piece of wood heated at one end in the fire so as to become black, does very well. Red oxide of lead and aqueous sulphate of copper are much used in practising the extraction of metals by the blowpipe.

478. If the outer flame is to be used, a slip of glass, with a small earthen cup at one extremity, Fig. 76, is the most convenient

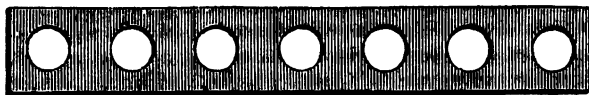
Fig. 76.



support; if the extremity be touched with a minute quantity of a solution of silicated potassa (321), it adheres firmly, and any substance placed upon it may be exposed with great facility to the action of the outer flame, and all the effects produced and seen with great distinctness.

479. These BLOWPIPE CUPS are prepared in the following manner. Procure a piece of brass, 1-20th of an inch thick, of the size shewn in Fig. 77, and with seven round holes in it. Place it

Fig. 77.



upon a slip of paper, and fill up the apertures with pipe-clay, previously mixed with water, and having the consistency of dough. Remove any superfluous clay with the finger; then press them with the finger, the brass mould and paper resting on the left hand, so as to give them a cupped form. Dry them slowly before the fire for an hour or two, and heat them to redness in a crucible to make them fit for use.

480. Heat iron, lead, copper, zinc, tin, bismuth, and antimony, on these cups, in the outer flame, and compare the effect produced with what is observed when they are heated on charcoal.

481. Fuse a little borax on several cups, using it alone on one, and touching the others with a little of each of the following substances: Binocide of copper gives a green glass; metallic copper is seen in the inner flame. Binocide of manganese produces an amethystine tint. Arsenuret of cobalt (common ore of cobalt) mixed with an equal weight of nitre, produces a fine blue. Proceed also with the borax on the cups as in 387.

482. Fig. 78. shews another form of the common blowpipe, fix-

ed to a small plate of lead, so that its motion can be regulated by the mouth, and the hands left free for experimenting. A form of gas-burner is represented there, which is much employed in blow-pipe experiments. The jet represented in Fig. 39. is also well adapted for this purpose.

Fig. 78.

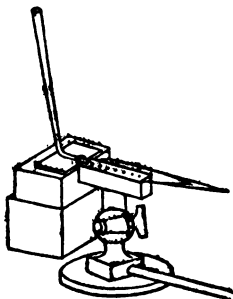


Fig. 79.



Fig. 82.



Fig. 80.

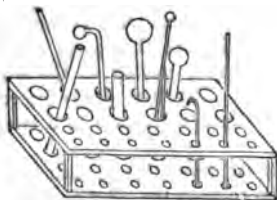
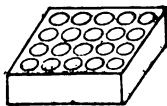


Fig. 81.



TUBE APPARATUS.

463. TUBES OF THIN GLASS, of the size and form shewn in Fig. 79, are extremely convenient for numerous experiments where gases are evolved, liquids to be boiled, or solids to be heated and sublimed. Cases for holding them may be easily made of wood, of the form represented in Figs. 80. and 81. Small retorts, receivers, and flasks, Fig. 82, are frequently made with tubes, for operating on minute quantities of different substances.

CHAP. XXXI.—MISCELLANEOUS APPARATUS.—MATERIALS FOR EXPERIMENTS.

484. Flasks of the form shown in Figs. 83. and 84. are much

Fig. 83.

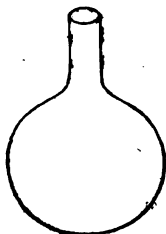


Fig. 84.

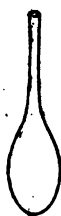
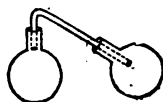


Fig. 85.



used in a variety of experiments. Fig. 85. represents two small flasks, or bulbs of glass, connected by an intermediate tube, so as to be used as a small retort and receiver. The wide flask, Fig. 83, if 4 or 5 inches in diameter, does well for burning phosphorus and other materials in oxygen; these are supported on a stand, as in Figs. 23. or 24, the cup being at a height equal to the length of the neck of the flask; the flask, full of oxygen gas, is then placed over the inflamed material, the mouth being placed downwards, and allowed to rest on rather a rough surface, that part of the oxygen may escape easily as the expansion proceeds.

485. Fig. 86. shows the form of a wooden stand with a number of apertures, very convenient for giving a temporary support to

Fig. 86.

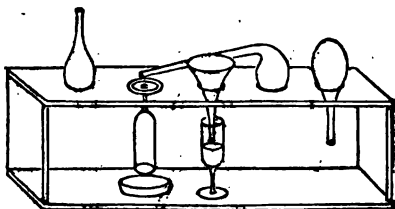


Fig. 87.



Fig. 88.



retorts, flasks, funnels, and other apparatus. Figs. 87. and 88. represent a square block of wood, with an aperture, and also a ring of tinned iron, which are often necessary in supporting flasks.

486. Fig. 89. is intended to give an outline of a very plain form of a retort-stand, which is extremely useful, and may be made in a very short time by any blacksmith. It consists of a small plate of wrought-iron, 7 inches long, 3 broad, and 1-2d of an inch thick. A stem rises 3-8ths of an inch in diameter, and 10 inches long. Rings are made of iron-wire, which are supported by coiling the wire $2\frac{1}{2}$ times round the stem. These may be moved readily upon the stem, but when any weight rests upon the extremity, they become quite fixed in their position.

Fig. 89.

Fig. 90.

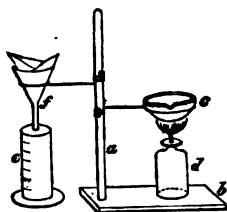


Fig. 91.

Fig. 92.



487. Figs. 90. and 91. shew the form of the long funnel for introducing liquids into a plain retort, and also a common funnel, such as is used for filtration. Fig. 92. represents a piece of filtering paper, folded in the manner required where liquids must be filtered quickly.

488. Figs. 93, 94; a rake and scraper required in furnace experiments. Figs. 95, 96; small wires of different kinds of metals, used for supporting minute quantities of materials in the flame of a lamp; platinum wires are preferred.

Fig. 93. Fig. 94.

Fig. 95.

Fig. 96.

Fig. 97.

Fig. 98.

Fig. 99.



489. Figs. 97, 98, 99, represent different forms of tongs and pincers. Fig. 100, a crucible and its cover. Fig. 101, a crucible

covered with another luted to it, gas being carried off at an aperture made in the top. Fig. 102, tin pincers.

Fig. 101.

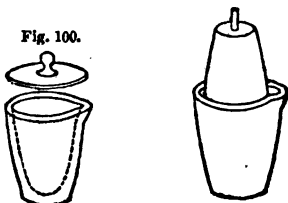


Fig. 102.



490. A conical piece of tinned iron, open above and below, being filled with clay, and a piece of hard wood of the same form, but a little smaller, being pressed into it, a crucible is at once obtained which must be dried and heated slowly before it is used. The tin and the wood must be well oiled to enable the crucible to be removed. Small crucibles, 2 inches deep, $1\frac{1}{4}$ wide at the top, and tapering a little to the bottom, are very convenient for numerous experiments.

491. In using retorts, flasks, and crucibles, they should not in general be filled more than 1-3d full, where the materials are apt to effervesce or boil over.

492. Pneumatic jars, see p. 44, Fig. 15, must be filled cautiously with water when they are mounted on the shelf, *b*, to prevent them from being knocked over by any sudden movement in the fluid; the spout *c* leads any excess of water into the box *f*.

493. Small pieces of tin, copper, iron, and zinc wire, plate or foil, are very useful in experiments on the small scale.

494. SOLUTIONS are usually prepared by merely agitating the solid with water, or some other solvent, if it be very soluble; the mixture is boiled if the substance be sparingly soluble.

495. EQUAL WEIGHTS are always understood when the term "parts" is used, unless parts by measure be specifically mentioned.

496. Cubic inches are expressed by c. i., weight by W, volume by V.

497. The following table may be frequently referred to, so as to enable the experimenter to calculate the weight of materials used from the amount of the common measure employed for chemical purposes.

	Specific Gravity.	Weight in Grains of		
		1 Ounce.	1 Drachm.	1 Minim.
Distilled Water . .	1.000	455.72	56.96	0.947
Sulphuric Ether . .	0.720	328.12	41.01	0.683
Alcohol	0.796	362.76	45.34	0.749
Solution of Ammonia .	0.925	421.54	52.69	0.878
Muriatic Acid . . .	1.118	509.50	63.68	1.061
Nitric Acid	1.480	674.47	84.30	1.405
Sulphuric Acid . . .	1.848	842.18	105.27	1.754

Memoranda :

60 drops or minims	=	1 dram.	
8 drams . . .	=	1 ounce.	
16 ounces . .	=	1 pint.	
8 pints . . .	=	1 gallon.	
Imperial pint .	=	374.5	grains of distilled water.
Imperial fluid ounce	=	437.5
Cubic inch . .	=	252.458
Pound, avoirdupois	=	7000
Ounce, avoirdupois	=	437.5

498. The small museums, price 6s., prepared by Mr Macfarlane, consisting of about 60 specimens, with bottles containing the most important acids and alkalis, and slips of glass, are extremely useful in enabling the student, who has neither time nor opportunity to operate with more extensive apparatus, to make himself familiar with a wide range of chemical phenomena.

499. The following list of materials and apparatus may be useful to those proposing to commence a series of experiments by themselves :—

[A * indicates that the substance before which it is placed should be kept in solution, as well as in the solid form. † is prefixed to those which may be kept in solution alone. Phials capable of holding from one dram to two or three ounces will do extremely well for this purpose. Boxes containing the materials, &c. represented below should not cost more than about three pounds : when of the larger size, and intended for Introductory Courses in Schools and Academies, from six to ten pounds may be expended upon them.]

Sulphuric, Nitric, and Muriatic Acids; Solution of Potassa and Ammonia,—all these must be kept in stoppled phials.

- | | |
|---|-----------------------------|
| Sulphur. | Iron. |
| Phosphorus. | Oxide of Iron. |
| Iodine. | Peroxide of Iron. |
| * Fused Potassa. | * Sulphate of Iron. |
| * Carbonate of Potassa. | † Permuriate of Iron. |
| Bicarbonate of Potassa. | Lead. |
| Sulphate of Potassa. | Sulphuret of Lead. |
| Nitrate of Potassa. | Litharge. |
| Chlorate of Potassa. | Red Oxide of Lead. |
| Bitartrate of Potassa. | Carbonate of Lead. |
| * Ferroprussiate of Potassa. | * Acetate of Lead. |
| * Bichromate of Potassa. | * Nitrate of Lead. |
| * Iodide of Potassium. | Ore of Cobalt (Arsenuret). |
| * Silicated Potassa. | Tin. |
| * Carbonate of Soda. | Bismuth. |
| Bicarbonate of Soda. | Antimony. |
| Phosphate of Soda. | Sulphuret of Antimony. |
| * Oxalate of Ammonia. | Copper. |
| * Carbonate of Ammonia. | * Sulphate of Copper. |
| † Hydrosulphuret of Ammonia. | * Nitrate of Copper. |
| * Chloride of Lime. | Zinc. |
| † Muriate of Lime. | Oxide of Zinc. |
| Sulphate of Lime. | Arsenious Acid. |
| Phosphate of Lime. | Sulphuret of Arsenic. |
| Phosphuret of Calcium. | Binoxide of Manganese. |
| Fluoride of Calcium. | Mercury. |
| Sulphate of Baryta. | Binoxide of Mercury. |
| * Nitrate of Baryta. | * Bichloride of Mercury. |
| Sulphuret of Barium. | Bisulphuret of Mercury. |
| Strontia. | Bicyanide of Mercury. |
| * Muriate of Strontia. | * Nitrate of Silver. |
| Magnesia. | † Bichloride of Platinum. |
| Sulphate of Magnesia. | † Terchloride of Gold. |
| * Alum. | † Tincture of Galls. |
| Silica. | |
| * Oxalic Acid. | Tartaric and Benzoic Acids. |
| Cabbage, Turmeric, and Litmus Test-Papers; Filtering Paper. | |
| Chalk or Marble, Sulphuret of Iron, and Borax, may be pro- | |
| vided in larger quantity. | |

Pneumatic Trough with Shelf	Retort, Stand, and Ring.
Pneumatic and Precipitate Jars, with Tin Trays.	Cupped Iron Block with Iron Bar.
Tube Retort, Receiver, and Funnel.	Triangular Supports made of Wires of different Metals.
Basin for evaporating.	Crucibles.
Watch Glasses.	Blowpipe.
Test-Tubes.	Blowpipe-Lamp.
Pipettes.	Blowpipe-Cups.
Bottle and Bent Tube.	Brass Mould for making them.
Spirit-Lamp.	Platinum Wire.
Glass Funnel.	Supports for Candles, Sulphur, Phosphorus, Test Tubes.
Slips of Glass for Solution, Eva- poration, Crystallization, Fu- sion, and Testing.	Iron-Wire, Slips of Copper and Tin.
Apparatus for Instantaneous Light.	Phials, Test-Tubes.

500. Paper dipped in different fluids is well adapted for illustrating a great variety of chemical phenomena. Dip different slips of paper into solutions of nitre, nitrate of lead, and nitrate of copper; dry them and set them on fire, so as to burn without flame; carbonate of potassa, highly alkaline, is produced with the first, metallic lead and copper with the others; the copper immediately attracts oxygen, and assumes a dull appearance.

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[*Moral Education.*] For the sake of himself and society, he must be habituated, from the dawn of consciousness and feeling, to the regulation of the inferior sentiments of his nature, and gradually to the due exercise of the higher sentiments—justice, kindness, and truth, towards his fellow-beings, and veneration towards the objects of his religious faith.

[*Intellectual Education.*] That he may be qualified for the ready acquisition of knowledge, and the performance of the duties and labours of life, he must be instructed in (1) Reading, at least in his own tongue, (2) Writing, (3) Arithmetic, and (4) Grammar and Composition. That he may enter life with a mind informed respecting that creation of which he is a part, and that society of which he is a member, and qualified as well as may be to perform the part which will fall to his lot, he must be acquainted with at least the elements of the following kinds of knowledge—(1) the Surface of the Earth (Geography); (2) the Structure of the Earth (Geology); (3) the Vegetable Productions of the Earth (Botany); (4) the Animal Creatures of the Earth (Zoology); (5) the Phenomena of the Atmosphere (Meteorology); (6) the Elements of Matter and their Combinations (Chemistry); (7) the Mechanical Powers and Relations of the Material World (Natural Philosophy); (8) the Science of Measurement (Geometry); (9) the Relation of our Globe to the other component parts of the vast System of Creation (Astronomy); (10) the Physical, Moral, and Intellectual Nature of Man, with reference to the preservation of health, and the attainment of happiness; (11) the Production and Distribution of National Wealth (Political Economy); (12) the History of Nations and Countries, Ancient and Modern, especially those in which the Pupil is most interested.

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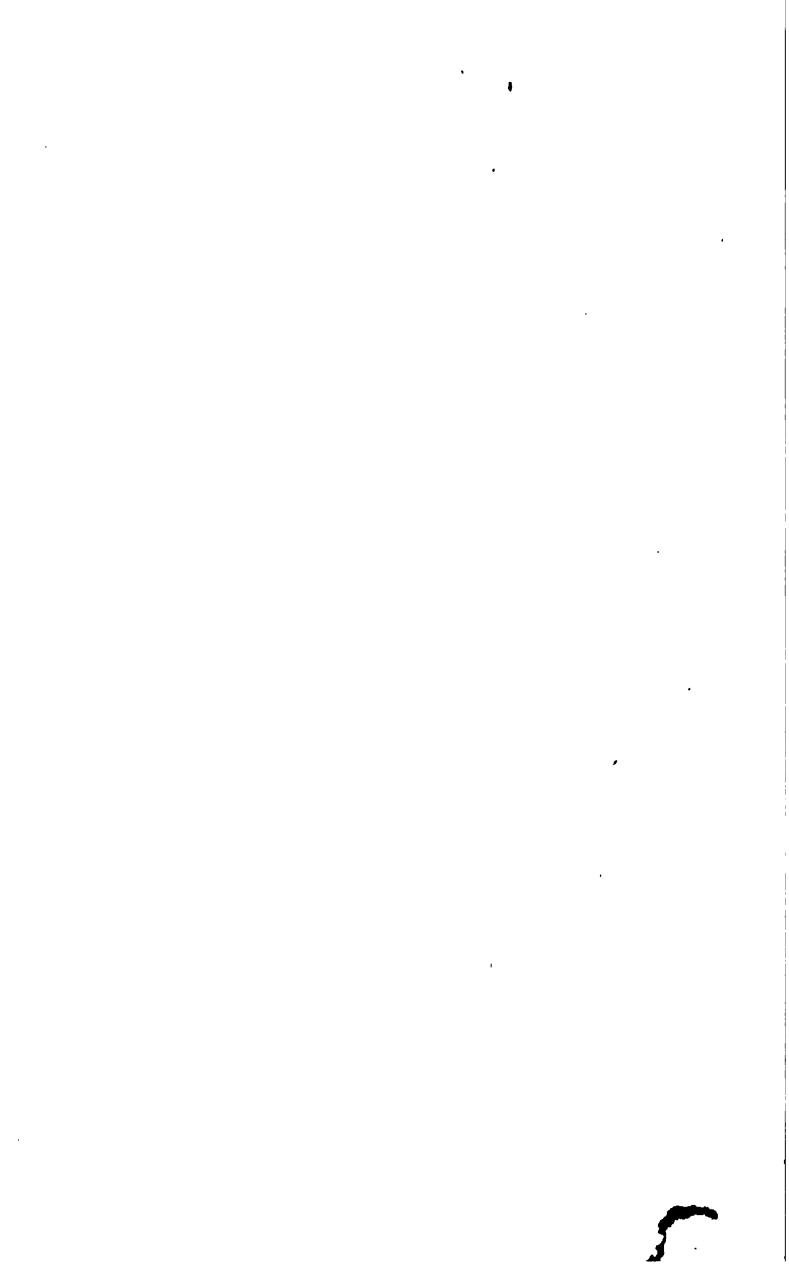
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